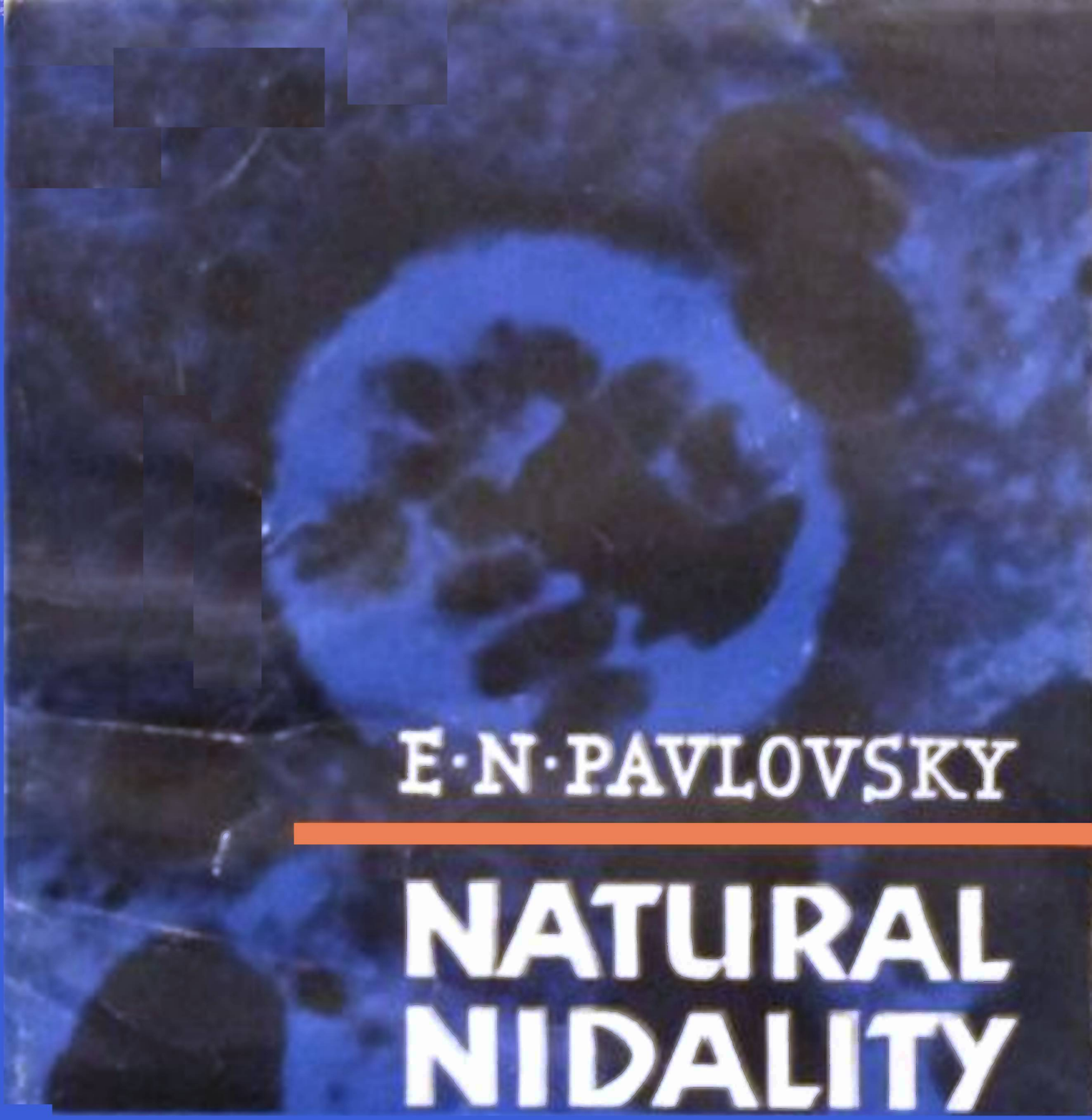

E·N·PAVLOVSKY

# NATURAL NIDALITY OF TRANSMISSIBLE DISEASES

*Academician E. PAVLOVSKY*

# NATURAL NIDALITY OF TRANSMISSIBLE DISEASES

## IN RELATION TO LANDSCAPE EPIDEMIOLOGY OF ZOOANTHROPONOSES

TRANSLATED FROM THE RUSSIAN BY YURI SHIROKOV

PEACE PUBLISHERS
MOSCOW

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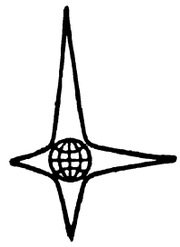

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*Академик* **Е. ПАВЛОВСКИЙ**

# ПРИРОДНАЯ ОЧАГОВОСТЬ ТРАНСМИССИВНЫХ БОЛЕЗНЕЙ

## В СВЯЗИ С ЛАНДШАФТНОЙ ЭПИДЕМИОЛОГИЕЙ ЗООАНТРОПОНОЗОВ

ИЗДАТЕЛЬСТВО «НАУКА» МОСКВА — ЛЕНИНГРАД

*На английском языке*

*Academician E. PAVLOVSKY*

# NATURAL NIDALITY OF TRANSMISSIBLE DISEASES

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This book contains an exposition of the theory of natural nidality of transmissible diseases. A successful study of this theory is closely related to a combined use of the ecologoparasitological, faunistic and biological methods forming the backbone of theoretical and clinical research in medicine. In the final analysis it provides the basis for the control of diseases with natural foci, particularly in view of their relationships with specific geographical landscapes, desolate, sparsely populated, or modified by human activities. The book is intended for biologists and physicians.

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# PREFACE

The present book is the first attempt at giving a systematic exposition of the theory of natural nidality of transmissible diseases in man. Since the basic principles of this multilateral theory were published in 1939, literature on its various aspects and specific details has come into being and continues to increase. It is natural that in the first variant of its exposition this extensive literature could be used only partially.

Although the author makes reservations concerning a partial use of the new literature on the subject, the editors will nevertheless appreciate readers' comments on the structure of the book, and their suggestions for its improvement and enrichment with the most important material from the extensive literature available. The author has also drawn upon the advice and useful suggestions of many of his pupils, followers and associates. Though their names are not listed so as not to make them even remotely responsible for his statements, their friendly assistance is acknowledged with gratitude.

All criticisms and suggestions should be addressed to the Peace Publishers, Moscow, U.S.S.R.

*Editors*

# CHAPTER I

# THE BASIC PRINCIPLES OF THE THEORY OF NATURAL NIDALITY OF DISEASES

## ZOONOSES, ANTHROPONOSES, ZOOANTHROPONOSES, TRANSMISSIBLE DISEASES

There are a great many diseases of man, animals and plants on Earth. The diseases of animals are grouped under the term *zoonoses* (derived from the Greek *zoion*—animal and *nozos*—disease). Many zoonoses are common *only* to animals and do not occur in man (for example, plague in cattle, pigs, etc.). Some zoonoses, however, can under certain circumstances be transmitted from sick animals to man directly or by a vector. The vectors are various invertebrate animals, mainly bloodsucking ticks and insects which, on biting a sick man or animal (or a healthy parasite host) ingest a disease-producing agent. When they subsequently bite a healthy man or animal, this agent is transmitted to the latter. Such diseases are known as *transmissible* diseases.

By this mode of transmission of a disease-producing agent by vectors certain zoonoses, for example, rabies, etc., are communicated to man. Also listed among such zoonoses are cases of asymptomatic invasion by microbes which, when transmitted to humans, exhibit obvious virulence.

The diseases in this group are called *zooanthroponoses* or *anthropozoonoses*, i.e., diseases common to animals and man (from the Greek *anthropos*—man, *zoion*—animal, *nozos*—disease) irrespective of their route of transmission to man.

But there are also certain diseases which at the present stage of evolution of the animal kingdom occur exclusively in man. They are few, however, for example, measles, scarlet fever and diphtheria among *non-transmissible* diseases, and human malaria among transmissible ones. Such diseases occurring only in man are grouped under the name of *anthroponoses.*

Hereafter these terms will be used without further explanation of the general meaning of the names of disease groups. This, how-

ever, does not rule out the need for a detailed description of the features peculiar to the process of transmission of disease-producing agents by vectors or of acquiring such agents through other routes and from other sources.

## PREREQUISITES FOR THE THEORY OF NATURAL NIDALITY OF DISEASES

Cases of various diseases affecting humans in diverse regions—the taiga, the steppes and deserts—have been known for a long time.

We have in mind not those diseases which may affect man in any locality but diseases typical of a particular place, to which people are susceptible in certain (undeveloped or underdeveloped) areas. These diseases are known as *endemic* *.

Such diseases depending on particular circumstances were isolated or spread among whole communities of people. For example, in the last century in the Central Asian semidesert along the river Murgab in Turkmenistan whole regiments, almost to a man, were afflicted with oriental sore otherwise known as Penjdeh sore. The cause of this mysterious phenomenon remained unknown until the 'thirties of this century.

Oriental sore, or cutaneous leishmaniasis, takes its name from the British surgeon W. Leishman who gave a scientific description of the causative agent of this disease (Fig. 1). But even before Leishman this parasite had been identified in Tashkent by Prof. P. F. Borovsky, who published a paper on his discovery in the *Journal of Military Medicine* (1898). Therefore, cutaneous leishmaniasis began to be called Borovsky's disease.

It owes its name, Penjdeh sore, to the Turkmenian oasis of Penjdeh, where this disease was frequent. It is also widespread in the tropical countries of the East (India, Iraq, etc.).

After the Great October Socialist Revolution, reports began to arrive about severe and apparently infectious diseases involving the brain in people who had stayed in wild taiga regions. These diseases affected woodcutters, topographers, road-builders, and residents of new villages which sprang up close to the taiga in cleared spaces. Some cases proved fatal. Many survivors were found to have paralyses of various groups of muscles—of the arms, neck, etc.—these lesions disabled them for the rest of their lives (Figs. 2, 3).

These examples of human diseases in natural surroundings have the following characteristics: *connection of a disease with a definite geographical landscape* (semidesert, Figs. 4, 5; taiga, Fig. 6) and

* Derived from ancient Greek: *en*—in, inside, and *demos*—country, place; *endemic*—characteristic of a certain place, territory, country.

F i g. 1. Penjdeh sore (oriental sore, cutaneous leishmaniasis).

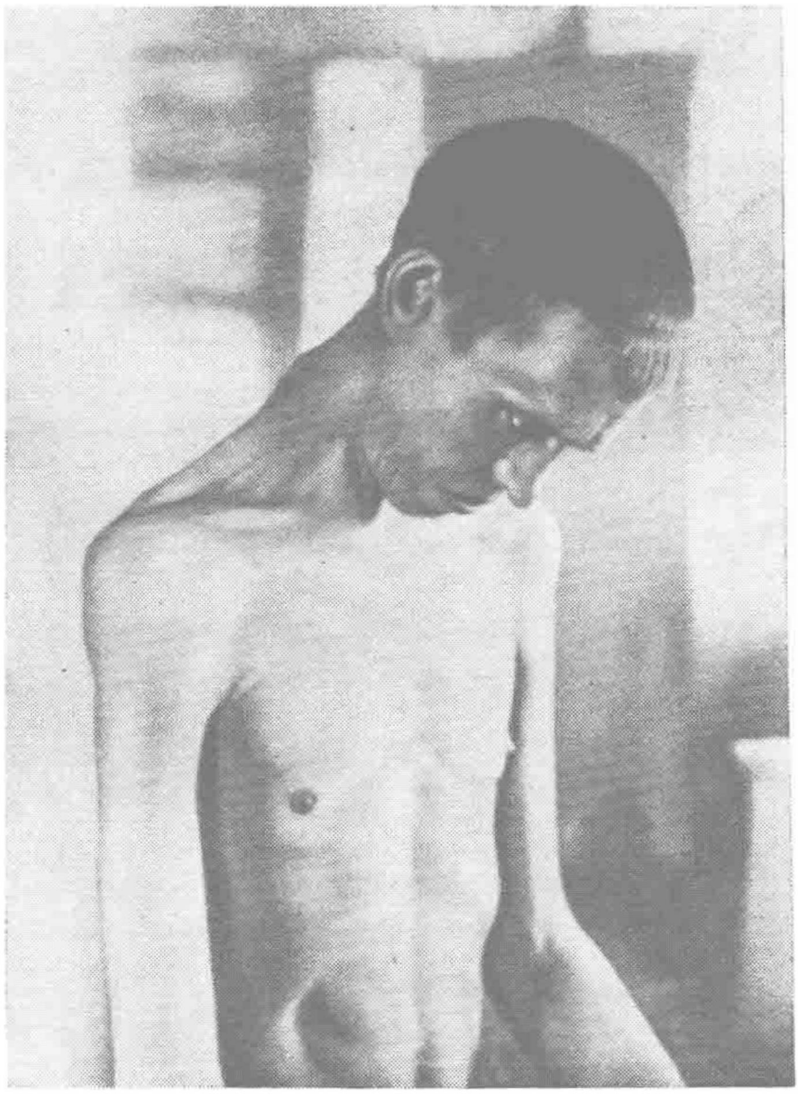
*seasonal outbreaks of a disease* (in the warm season of the year, in spring and early summer, etc.—Fig. 7).

The circumstances contributing to the occurrence of diseases in natural surroundings needed an explanation, even if preliminary, which was based on certain assumptions or working hypotheses.

In uninhabited localities, infection of man by man is out of the question; therefore, the source of a disease should be sought among the local fauna. Various geographical landscapes must apparently have the following inhabitants:

(1) causative agents of transmissible diseases, i.e., diseases spread by the agency of *vectors*, mainly bloodsucking insects and ticks. By biting an animal or man with a disease-producing agent in their peripheral blood, a vector also becomes infective, receiving the pathogen in the ingested blood; within the vector the disease-producing agent may either multiply directly or pass through a part of its complex life-cycle, at the end of which the vector becomes *infective* and capable of transmitting the pathogen (i.e., of infecting healthy susceptible humans or animals) through a bite;

(2) animals which may be *the donors* of the causative agents of these diseases to vectors;



F i g. 2. Residual symptom in a person recovered from tick-borne encephalitis. Paralysis of the cervical muscles. The Far East, 1938. Photo by A. V. Gutsevich.

(3) vectors themselves, specifically those species of bloodsucking ticks or insects, which transmit the pathogen they receive from a donor to susceptible animals called *recipients*. Under certain conditions, man can also be a recipient of a causative agent.

The study of the mysterious diseases people are likely to be infected with in natural surroundings made it necessary to send expeditions to corresponding localities to carry out surveys on the spot.

The basic centres of such research carried out by the author and his associates were successively the S. M. Kirov Academy of Military Medicine, the former A. M. Gorky All-Union Institute of Experimental Medicine, the Department of Parasitology and Medical Zoology at the Academician N. F. Gamaleya Institute of Epidemiology and Microbiology under the U.S.S.R. Academy of Medical Sciences, the Institute of Zoology under the U.S.S.R. Academy of Sciences, the Tadjik branch of the U.S.S.R. Academy of Sciences, now the Academy of Sciences of the Tadjik Republic, and other

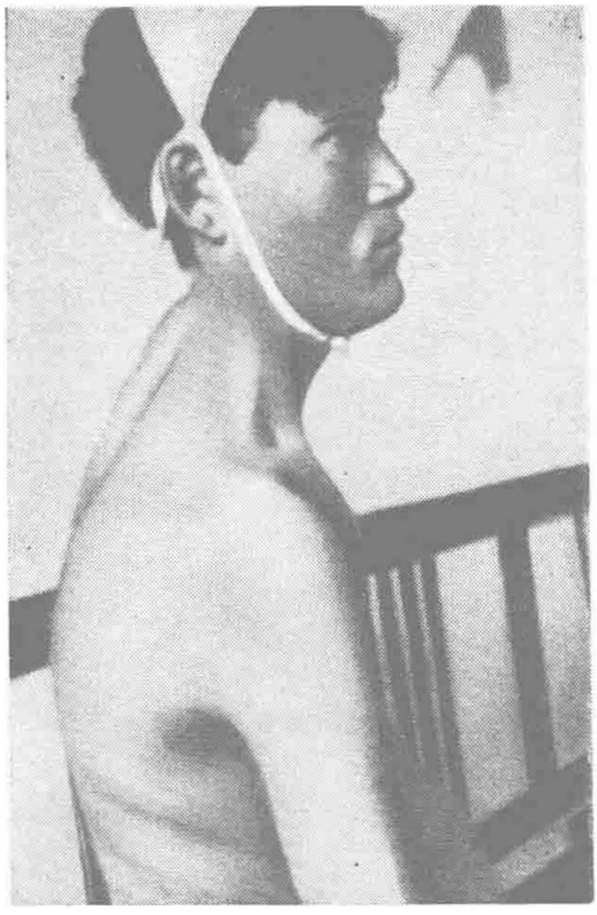


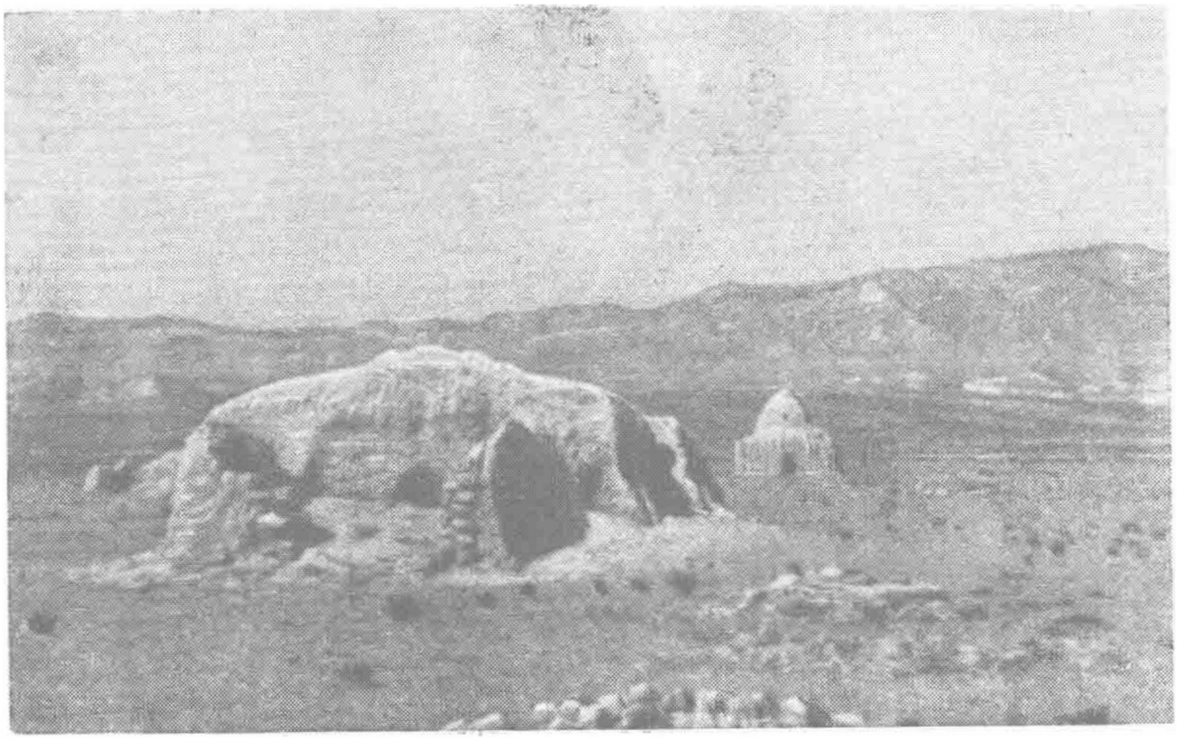
Fig. 3. Tick-borne encephalitis. Paralysis of the mandibular muscles. The Far East, 1937. Photo by A. V. Gutsevich.

institutions within the system of the U.S.S.R. Ministry of Health and the Academies of Union Republics, particularly of the Kazakh Republic, etc.

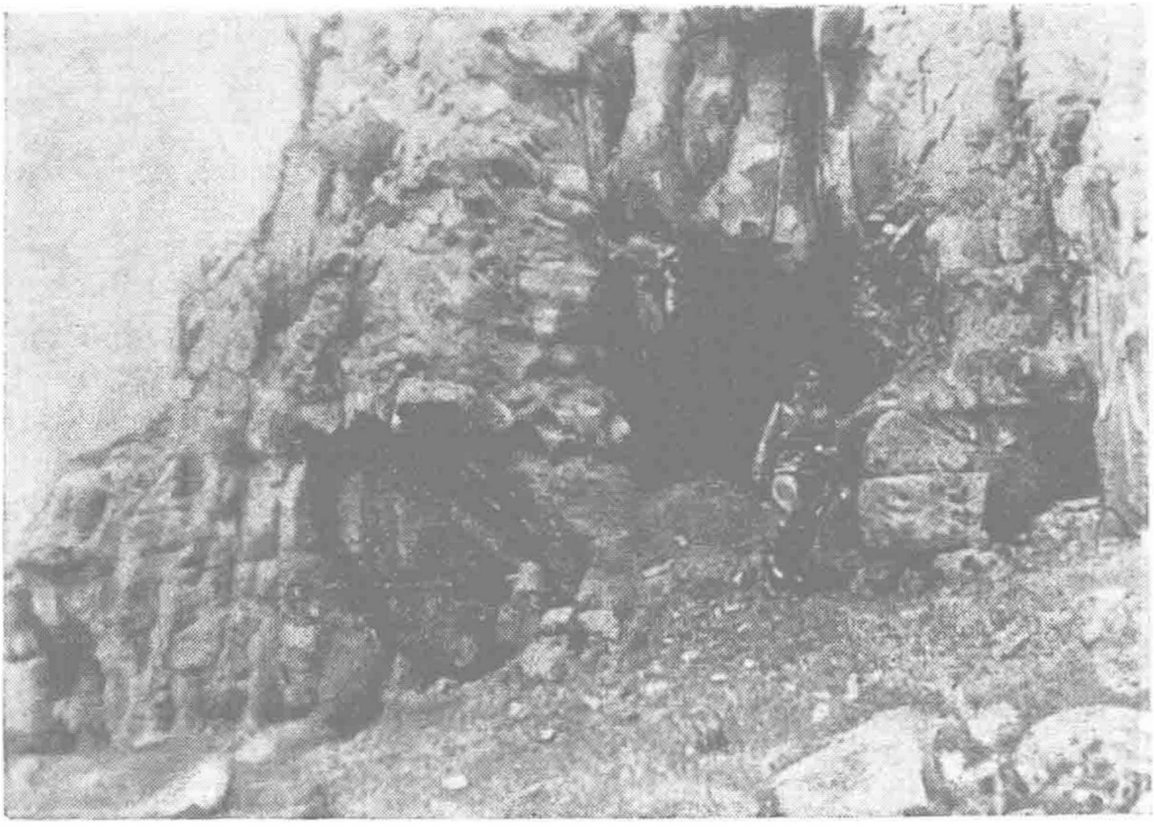
Guided by the above prerequisites, personal investigations, field and experimental studies were carried out by the author and many other research workers during numerous scientific expeditions. The results of this research, together with an analysis of the available scientific literature on medicine, veterinary medicine and biology, led the author to summarize his views of *the natural nidality of transmissible diseases* in the form of a theory, which is basically applicable to parasitic diseases also. Moreover, the problems of studying the focal character of certain non-transmissible infections have also been raised of late.

*Non-transmissible diseases* is the collective name given to those infections whose agents are not vector-borne, for instance, smallpox, diphtheria, scarlet fever, etc. Their agents may be communicable directly from a sick to a healthy person by contact, by inhaling air contaminated with a disease-producing agent when talking, coughing or sneezing (*respiratory route of infection*), etc.

The agents of certain diseases are spread with and without the aid of vectors. For example, the plague-like disease tularemia is

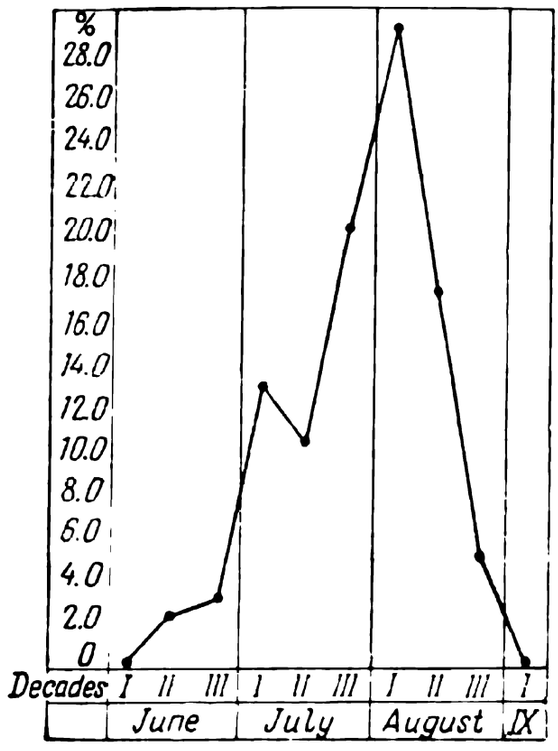


F i g. 4. Old "mazars" (tombs) near Geok-Tepe in Turkmenia—habitats of ticks and *Phlebotomus* sandflies. Photo by P. A. Petrishcheva (1960).



F i g. 5. A cave in the Karakalinsky district of Turkmenia—a focus of tick-borne spirochetosis. Photo by P. A. Petrishcheva.

F i g. 6. The virgin taiga—a focus of tick-borne encephalitis in the Far East.




F i g. 7. Changes in disease incidence according to decades in a transmissible outbreak of tularemia. From the monograph *Tularemia* by N. G. Olsufyev and G. P. Rudnev (1960).

transmitted not only by at least 40 species of vectors but also in the process of skinning tularemia-affected water rats, and from contact with water containing dead water rats; anthrax may be communicated by wearing felt boots and coats made from the wool and skins of animals killed by anthrax, etc.

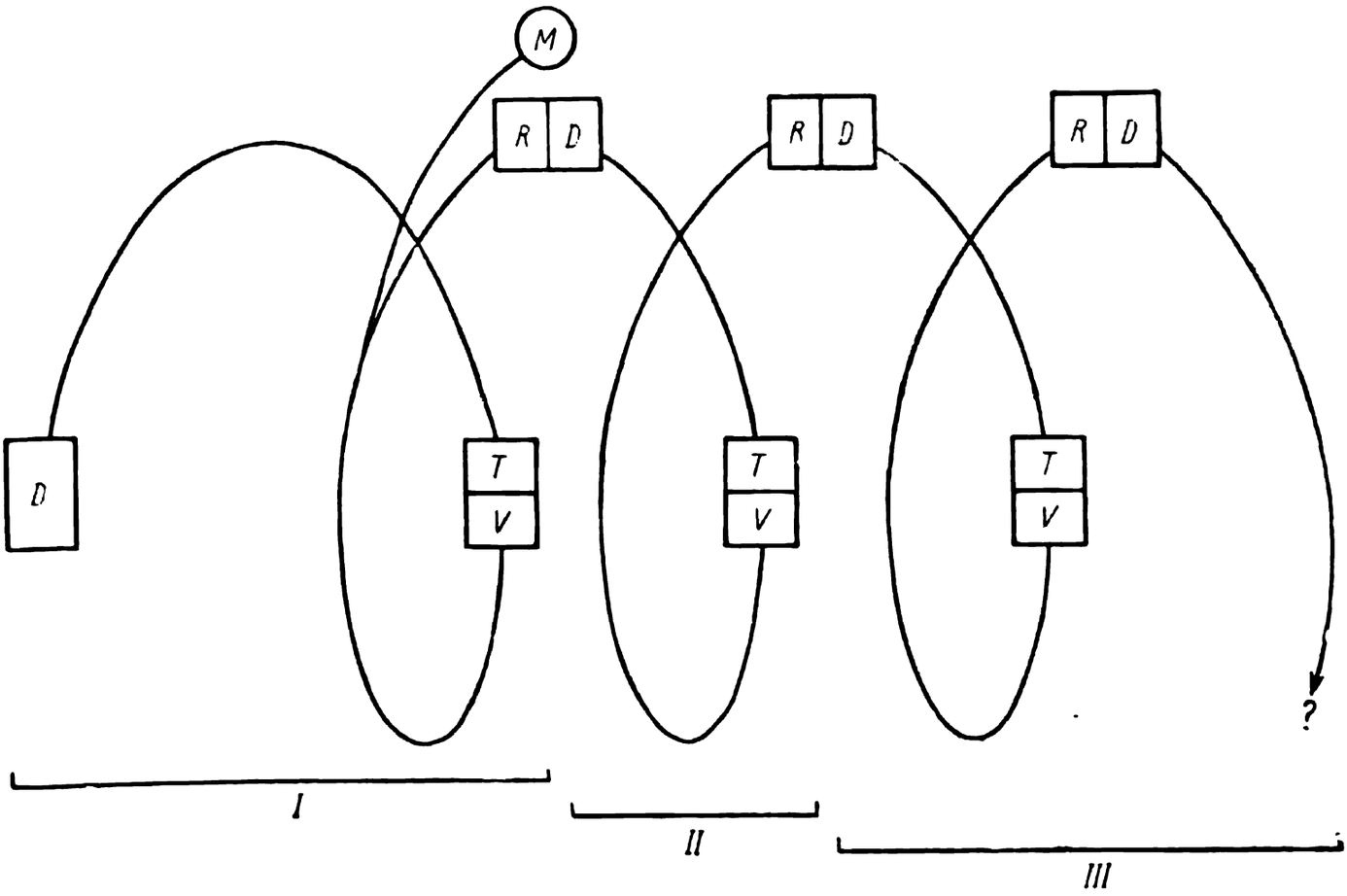
It is characteristic that the agents of most transmissible diseases are spread *only by vectors* (yellow fever by mosquitoes, malaria by *Anopheles* mosquitoes, tick-borne encephalitis by the *Ixodes persulcatus* and other *Ixodes* ticks, etc.). Such diseases are known as *specific obligato-transmissible* diseases. The pathogens of other diseases are transmitted by various routes, including vectors. Such diseases, the so-called *facultative* or *potentially transmissible diseases* are, for example, enteric fever, cholera, tularemia, plague, etc.

A number of transmissible diseases are characterized by their foci being confined to an environment untouched by man or modified by man, intentionally or unintentionally, in the past or at present. The foci of such diseases are known as natural foci and the corresponding diseases as *diseases with natural foci.*

What we call the natural nidality of transmissible diseases is characterized by the following features:

(a) The existence of any transmissible disease depends on *the successive transit of its causative agent from the body of the animal donor* (sick animal, asymptomatic virus carrier or parasite host) *to the vector body. This transmission usually takes place when the vector draws blood from the donor and subsequently transmits the causative agent to the animal recipient, commonly when drawing its blood also; the infected recipient may* in its turn *become a donor for another group of vectors,* etc. In this manner, there occurs, as we say, *circulation* (spiral-type circulation, Fig. 8) of the causative agent from organism to organism in one and the same or another population of the natural focus of a disease. The circulation of a pathogen, beginning from its reception by a vector from an animal donor and including the time required for the vector to become infective and infect the animal recipient which in its turn becomes a donor of the pathogen for a fresh vector, is called the complete cycle or tour of the pathogen during its circulation. But such a cycle is not a complete round since the next time the pathogen is transmitted by a vector it goes not to the animal from which it came originally but to another animal of the same population or an animal of another systematic position (from another specific population). This consecutive transmission of the pathogen occurs as though in a spiral form. The vector which has received the pathogen from a wild donor may transmit it also to man who then becomes **infected** and **develops the corresponding disease.**

(b) This circulation *takes place only when the environmental conditions are favourable* (for instance, at a definite temperature) *or at any rate do not obstruct any of the stages.*




F i g. 8. A diagram showing the "spiral" transition (circulation) of tick-borne encephalitis virus from organism to organism (D, RD) in a natural focus of disease by the agency of tick vectors (TV). Drawing by E. N. Pavlovsky.

M—infection of man from ticks (T) having acquired the virus from a wild animal—virus donor (D); (RD)—one and the same animal: (R) as a virus recipient, (D) as a virus donor (in the period of virusemia); (M) cul-de-sac in subsequent virus circulation (man); (TV) one and the same tick individual: (T) as a virus recipient, (V) as a virus vector. *I*, *II*, *III*—tours of circulation.

A natural focus of disease exists when there are a specific climate, vegetation, soil, and favourable microclimate in the places where vectors, donors, and recipients of infection take shelter. In other words, *a natural focus of disease is related to a specific geographical landscape*, such as the taiga of a certain botanical composition, a hot sand desert, the steppe, etc., i.e., *a biogeocoenosis*.

*Man falls victim to an animal disease with natural foci only when he stays in the territory of its natural focus at a definite season of the year, and is attacked* as prey *by hungry bloodsucking vectors* which have already acquired infection from biting wild animals—the carriers and donors of this disease. This accounts for **the seasonal occurrence** of such diseases; indeed, vectors in natural surroundings are not, as a rule, active round the year, but only in a fairly warm season.

Not every individual of a given vector species transmits infection but only those which have acquired it from an animal donor and,

under the influence of environmental factors, have reached an infective stage, i.e., have become capable of infecting other animals and man. In such cases, a vector acquires *natural* or *spontaneous* infectivity and *an infective power*.

A natural focus of disease harbouring hungry naturally infected vectors is said to be in *a latent state*, i.e., capable of infecting both animals and man.

The natural foci of certain diseases may occur in geographical landscapes of varied character, in which they are connected with specific **biotopes**, otherwise called habitats. In mountainous areas, important features are the elevation above sea level, and whether the mountain slopes face north or south; the disease foci are associated with burrows (Fig. 9), crevices, overhanging rocks, caves, spaces under stones (Fig. 10), and mountain streams. In the plain disease foci are associated with river creeks, flooding rivers and lakes; on the sea coast — with small residual reservoirs, etc.

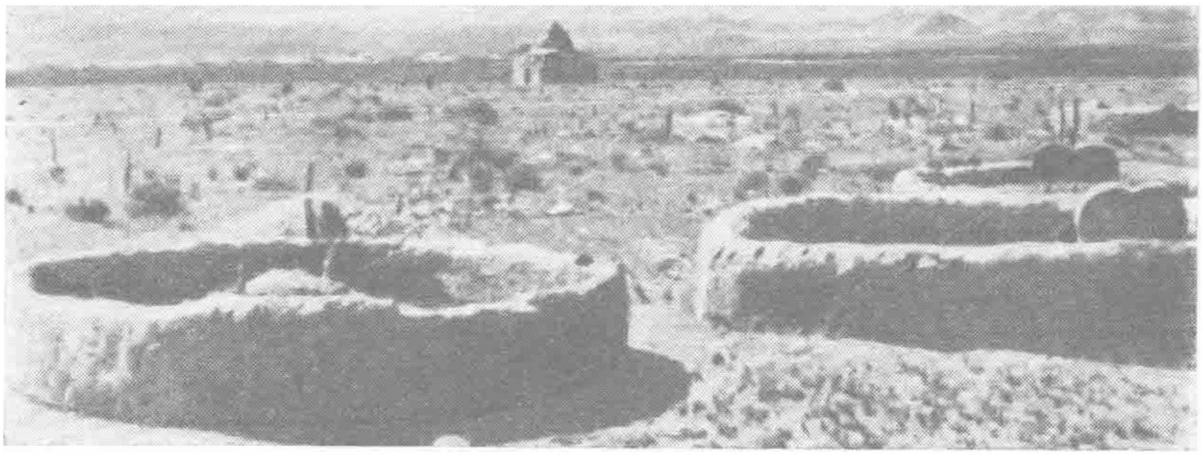
Other diseases with natural foci are more markedly linked with definite landscapes; the foci of the Penjdeh sore of the desert (rural) type are linked with the semidesert zone.

One and the same geographical landscape may simultaneously have natural foci of two or three diseases, and one and the same specific focus may harbour causative agents of different diseases. A focus is said to be *polyvector* if it is inhabited by *several types of vectors* sometimes even belonging to widely different systematic categories. One example is the rodent burrow in Central Asia (Fig. 11).

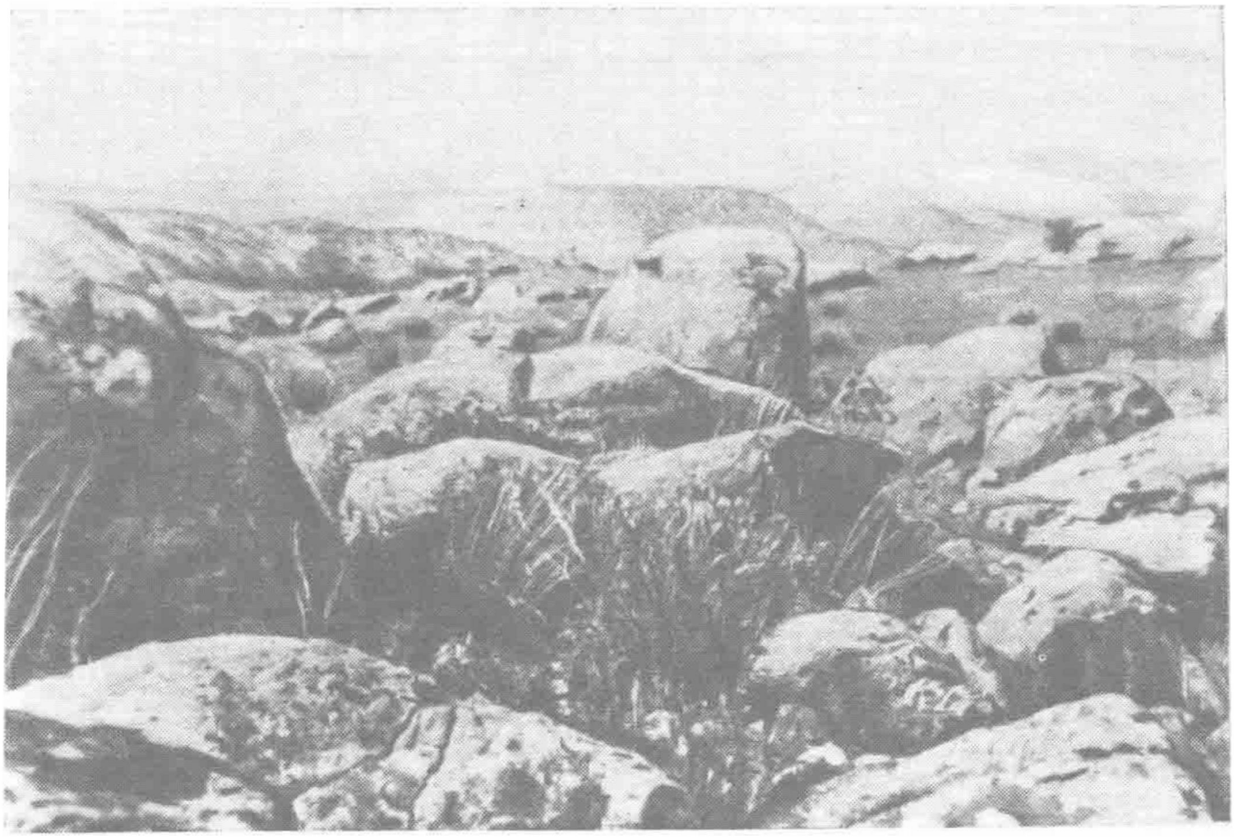
Such foci of two or three diseases existing simultaneously are known as *conjugate*, for instance, the foci of tularemia and plague, Penjdeh sore and tick-borne relapsing fever, etc.

When inhabited by several species of animals—donors of a causative agent — a natural focus of disease is said to be *polyhostal* in regard to the disease-producing agent.

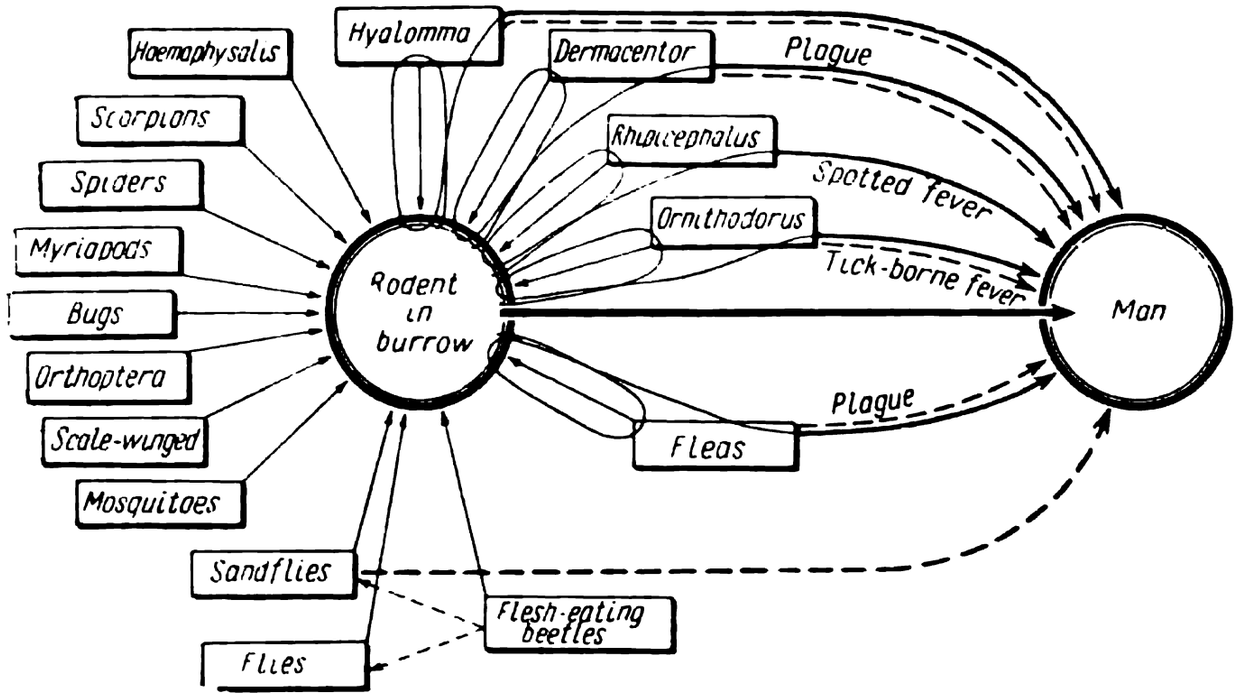
The following diseases are at present known to have natural foci: tick-borne spirochetosis, tick-borne and Japanese encephalites, highly virulent infections (tularemia, plague), lymphocytic choriomeningitis, equine encephalomyelitis, tick-borne rickettsioses, desert-type cutaneous leishmaniasis, listerellosis, erysipeloid, hemorrhagic fevers, nephroso-nephritis, and apparently brucellosis, rabies, ornithoses, etc.; among the helminthiases—opisthorchiasis and diphyllobothriasis, trichinellosis, bilharziasis, etc. It is quite probable that a viral disease such as pappataci fever as well as psittacosis, leptospiroses and other diseases also have natural foci. Outside the Soviet Union, diseases originating in natural foci are jungle yellow fever, kala-azar in Africa, trypanosomiases (African sleeping sickness) and others. The isolation of the causative agent of pseudotuberculosis of rodents along with plague cultures in the Tsagan-Nur district of the Mongolian People's Republic from the



F i g. 9. An ancient Moslem cemetery near Geok-Tepe. Destroyed graves contain burrows of tortoises and hedgehogs—hosts of *Ornithodoros* ticks (anthropurgic foci of tick-borne spirochetosis); the burrows are breeding-places of *Phlebotomus* sandflies. Turkmenia. Photo by P. A. Petrishcheva.



F i g. 10. Stone heaps under which *Phlebotomus* sandflies and ticks take shelter. Turkmenia. Photo by P. A. Petrishcheva.




F i g. 11. Diagram showing summary epidemiological significance of the rodent burrow biocoenosis as a natural focus of various diseases of man and animals (anthropozoonoses). Drawing by E. N. Pavlovsky.

*Arrows* indicate members of biocoenosis, venomous (scorpions and spiders) or harmless to man; *oval lines* show the route of transmission of pathogenic agents from rodents to man

narrow-skulled vole gives one reason for attributing pseudotuberculosis to diseases with natural foci also.

The number of known diseases with natural foci is steadily growing and will continue to grow as research advances, particularly in the tropical countries. There are frequent cases of the discovery of new viruses transmitted by *Arthropoda* — ticks or mosquitoes (arbor-viruses).

Animals which are donors and recipients of the causative agent of a transmissible or parasitic disease, the agent itself (of whatever nature) and infection vectors are all members of a pathobiocoenosis (E. N. Pavlovsky) associated with a specific biotope (or several biotopes) of a particular geographical landscape, or of a biogeocoenosis (as defined by Academician V. N. Sukachev).

## THE NATURAL FOCUS OF DISEASE AS A PATHOBIOCOENOSIS

The term "biocoenosis" or "community" of animals and plants should by no means be interpreted in the "human" sense, i.e., anthropomorphously. The members of a biocoenosis are correlated in different ways, these correlations being called biocoenotic relationships. Such relationships differ in character; they may be tro-

phic, when one of the members of a biocoenosis is fed upon by another, or "contact", when some members of a biocoenosis come into contact or some lead of association with others.

The term "*contact*" (which is rejected by certain specialists as "scientific jargon") has a literal meaning of actual contact and a general meaning of "association" if the latter has not so far been specifically defined. Indeed, we say sometimes about friendly contact, a feeling of fellowship in common work, etc., and these words do not sound odd to anyone, although this feeling by no means implies physical contact.

*The causative agent of a transmissible disease is also a member of the biocoenosis of its natural focus* (filtrable viruses, *Rickettsia* organisms, spirochetes, various bacteria, protozoan parasites, parasitic worms, etc.). The causative agents of certain diseases at the present stage of evolution of life on Earth never occur in the external environment but always pass from organism to organism, e. g., the malarial plasmodium.

Inasmuch as the disease-producing agent is also a member of a biogeocoenosis, there is reason to use the term *pathobiocoenosis.*

*All correlations in a biogeocoenosis* between the disease-producing agent, its donors, vectors and recipients *took shape in the process of evolution of organisms and interspecific correlations associated with a particular environment utterly irrespective of man, and, at least for certain diseases, perhaps even before the appearance of the human race.*

A biogeocoenosis exists as long as there is a minimum number of its requisite members which characterize the biocoenosis as such.

In the event of loss from its composition (for some natural or artificial reasons) of species of prime importance for supporting the biocoenotic relationships determining the very existence of a biocoenosis, the latter disintegrates, or, as it is said, there occurs *destruction* or *succession* of the biocoenosis: for example, in cases when certain important members of a biocoenosis have perished from cold during a severe winter, or vegetation they use for food has been destroyed by a drought, or such species have been exterminated by man, etc.

And conversely, *in the process of acclimatization, man introduces new animal species into the local fauna*, for instance, the muskrat (Fig. 12). It adapts itself to new surroundings easily, becomes a member of a biocoenosis and, on account of its susceptibility to infection with tularemia, becomes a new vector of tularemia in a given locality, from which it may perish en masse during the hunting season, and may transmit the disease to people-personnel of muskrat trapping stations and trappers, as has been the case during trapping seasons.

F i g. 12. Muskrat. A rodent introduced into the fauna of the U.S.S.R. The Karelian Isthmus. Photo by N. D. Mitrofanova.

Consequently, although biocoenoses have formed in the process of evolution independently from man, the latter, at the present stage of evolution of the animal kingdom on Earth, is exposed to their influence and, conversely, may himself influence biocoenoses; for instance the DDT pesticide used to control ticks and many other harmful insects also destroys useful insects, such as honeybees and other pollinators of plants, which drastically changes the composition of biocoenoses in a given locality.

Such forms of influence produced by human activity on nature and on natural foci of disease are called *anthropurgic* (from *anthropos*—man, and *urgeo*—to do, or act).

*The biotope*, or *the dwelling place*, is the habitat of an animal member of a biocoenosis or of a biocoenosis as a whole, for example, the puddle in a hollow tree is the biotope of larvae of certain mosquitoes (Fig. 13), hollow trees proper for bats and for mosquito imagoes, wet soil on river banks for horsefly pupae, rodent burrows and birds' nests for insects, etc.

## ELEMENTARY DISEASE FOCI, THEIR FORMS AND SPATIAL DISTRIBUTION

Natural foci of disease may be confined within narrow limits and isolated: for example, a rodent burrow (Fig. 14); in a definite section of a geographical landscape they may occur in large

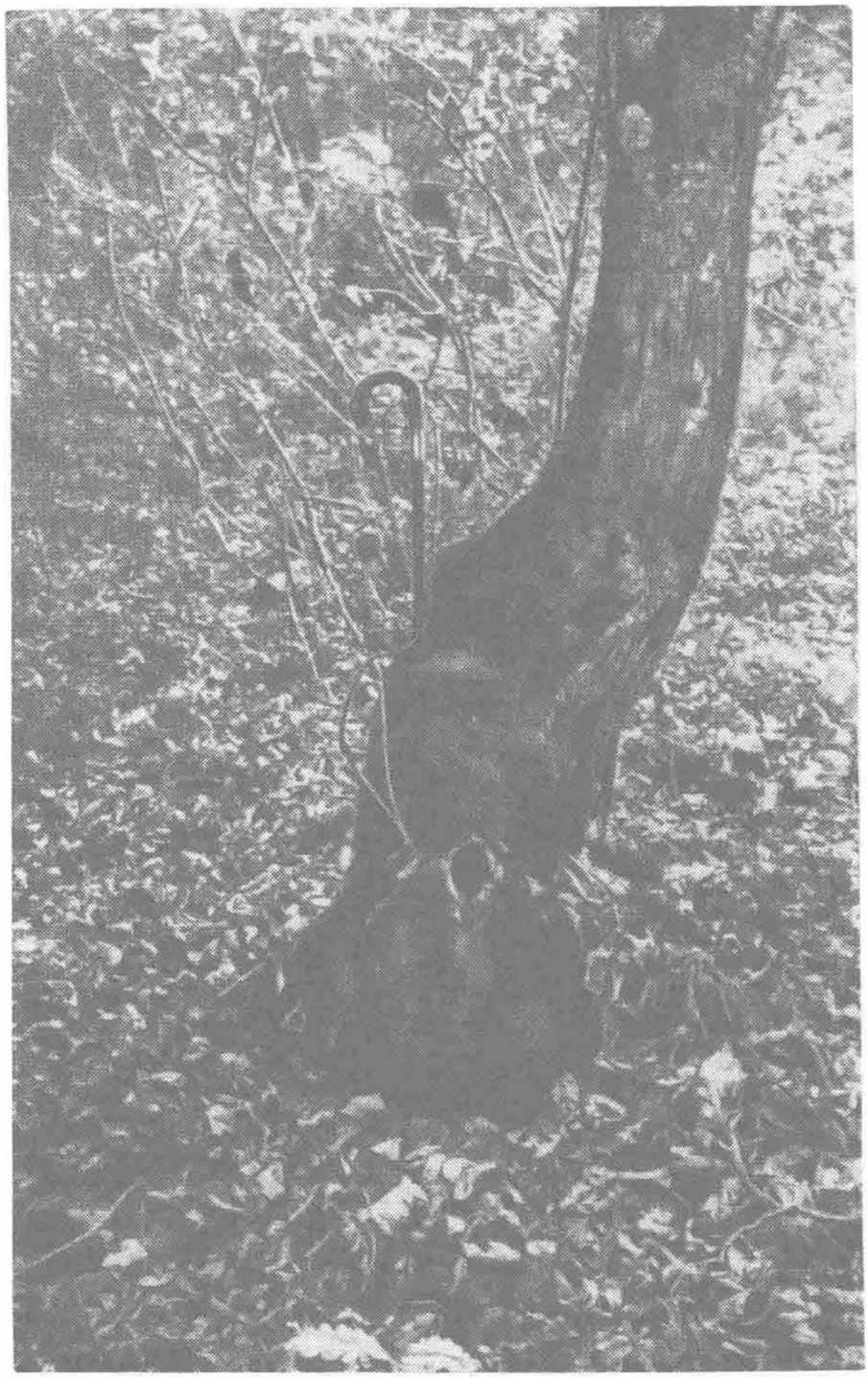


Fig. 13. A hollow tree—receptacle for a tiny water pool. An example of a biotope (habitat of larvae and a hatching-place of bloodsucking mosquitoes). The environs of Pyatigorsk. Photo by E. N. Pavlovsky.

numbers, for instance, colonies of *Rhombomys opimus*—the large gerbil (Fig. 15), in which many burrows communicate with one another, forming an intricate labyrinth of interconnected passages (Figs. 16, 17). Such ramified underground passages in a colony with a host of outlets undermine the layers of sand, so it becomes impossible to ride over the site of this colony on horseback or in a cart, because the horse's legs and cart wheels will be swallowed by sand.

Natural foci of disease may also be of another type, namely, diffuse, in which animals—donors and recipients—along with vectors of a disease-producing agent inhabit the wide territory of a geographical landscape; for example, broad-leaved forests are the zone of natural foci of tick-borne encephalitis. The thick litter of fallen dry leaves loosely lining the ground in such forests is especially favourable to the free life of ticks transmitting the virus of this disease; this leaf litter has no defined outlines (Figs. 18, 19). In the area of a diffuse natural focus crawling vectors are not found in every point; for instance, *Ixodes persulcatus* ticks, vectors of tick-borne encephalitis virus, concentrate in the taiga on paths along which animals usually go to their watering place or which

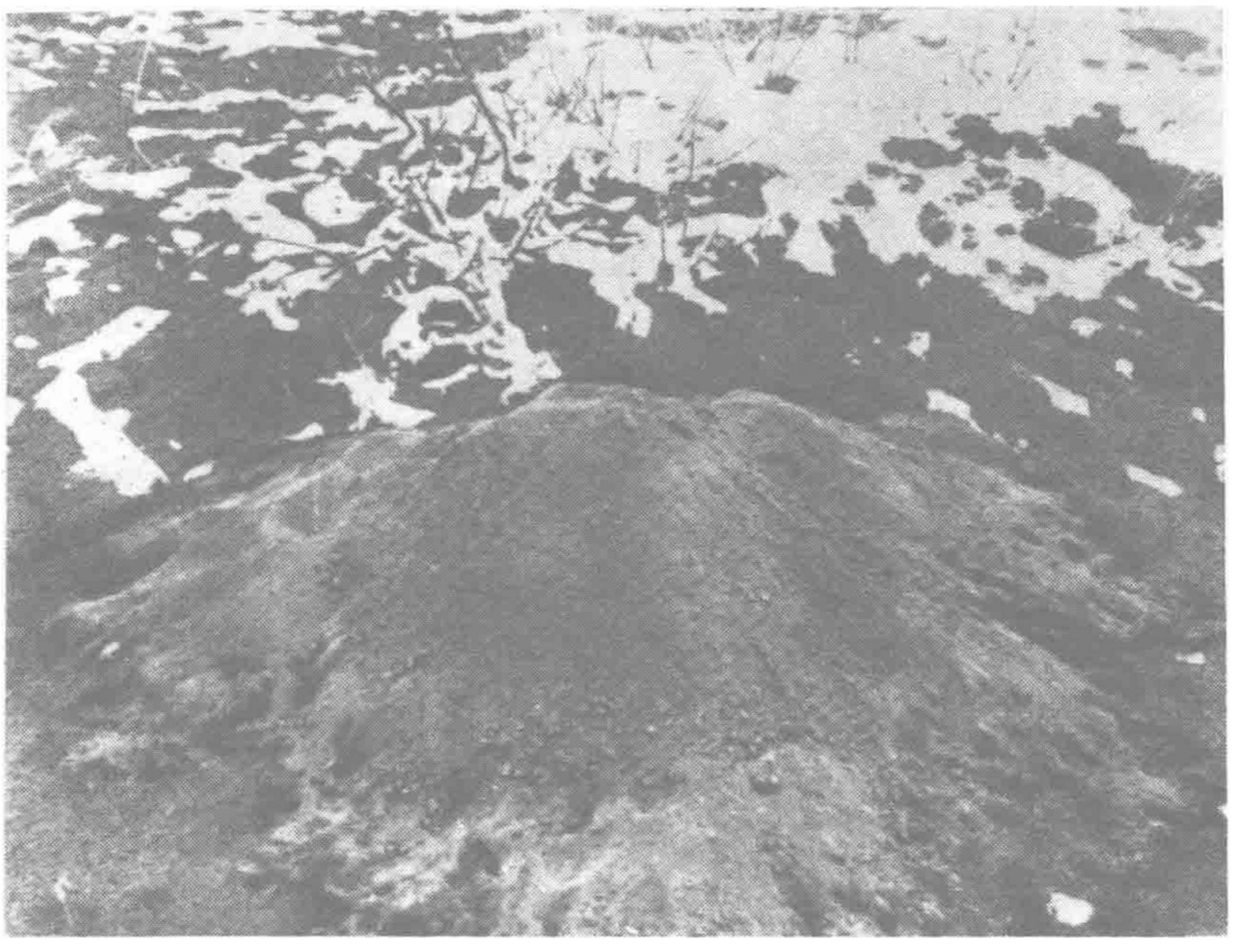


Fig. 14. The burrow of a thin-toed suslik in a sand region near Ashkhabad in winter. An elementary focus of tick-borne spirochetosis. Seen in picture are sand thrown out of the burrow and remnants of snow. Photo by Y. P. Vlasov.

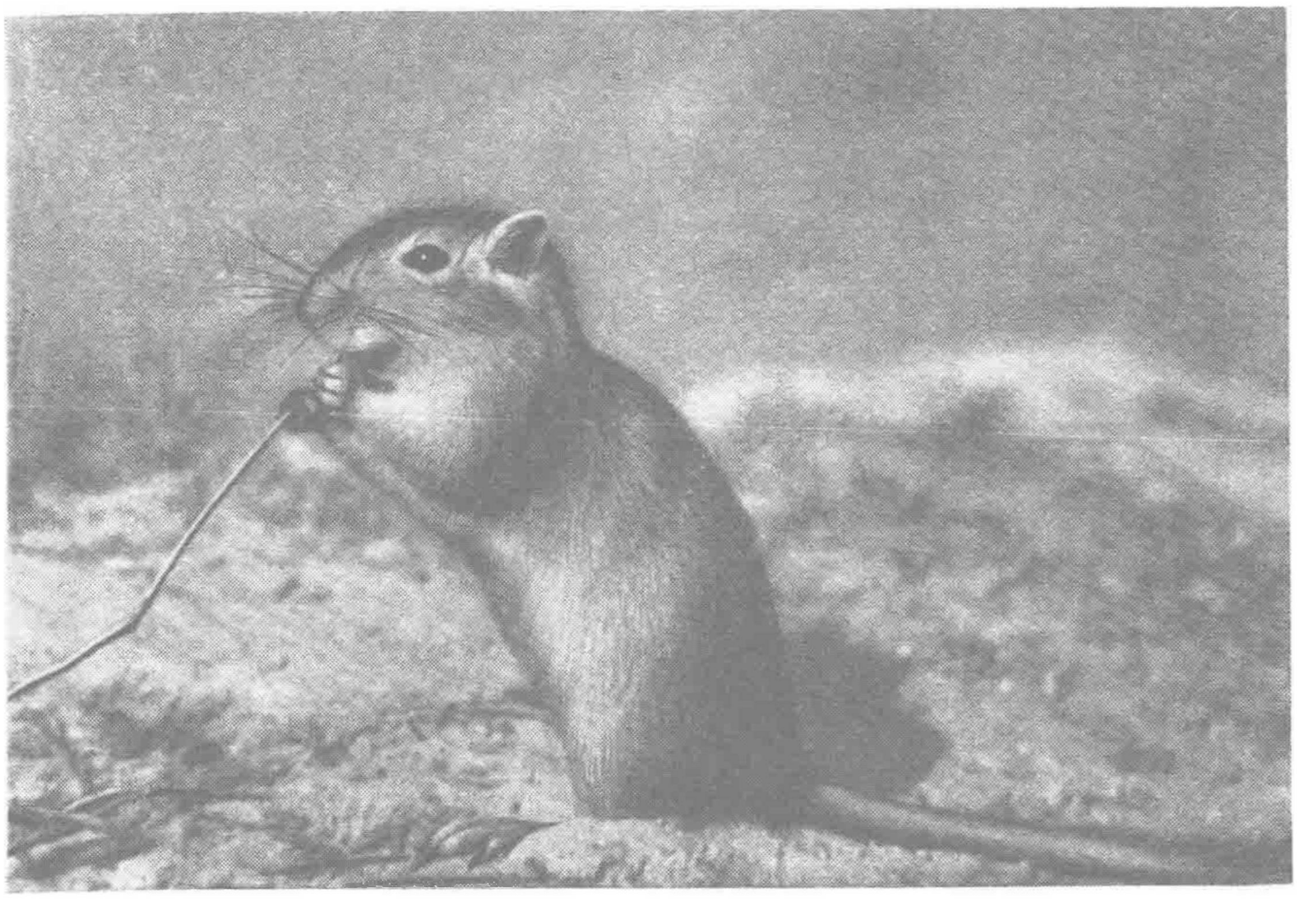
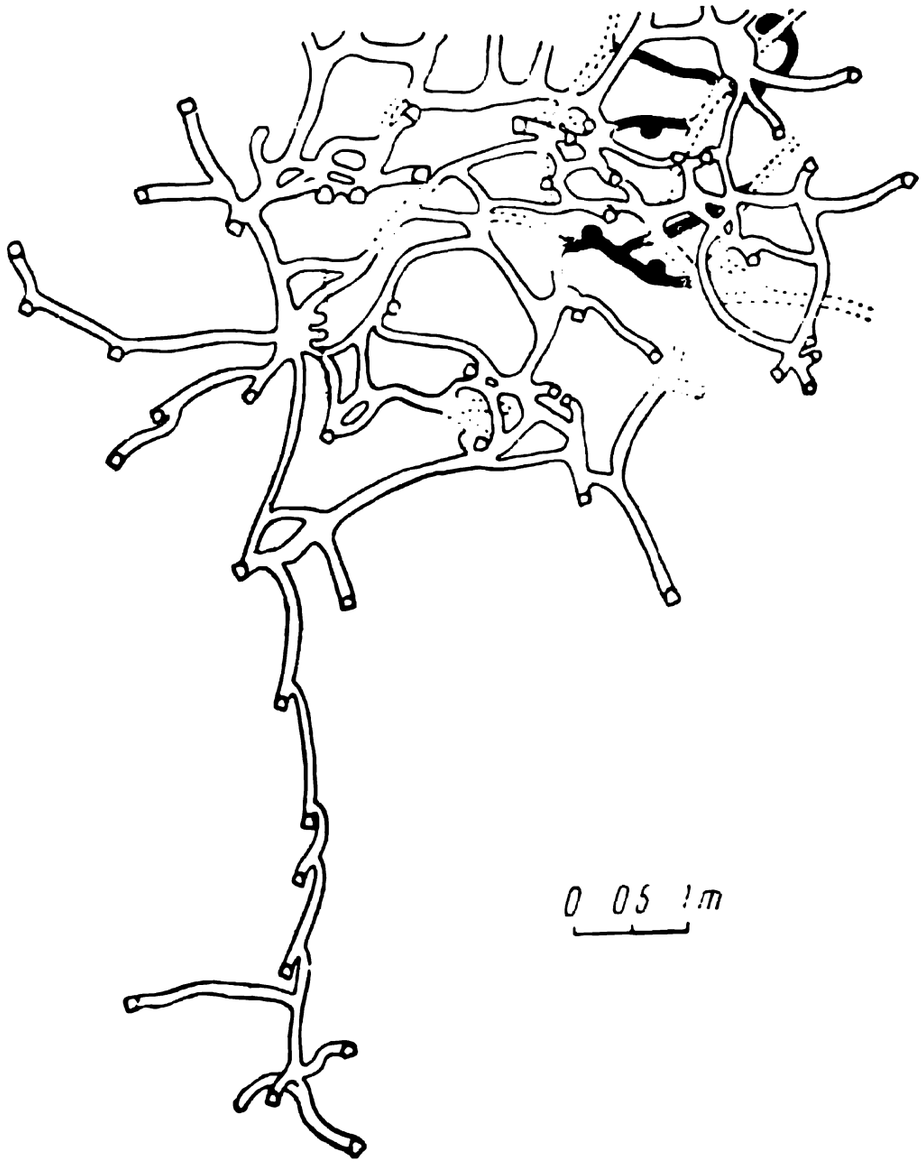


Fig. 15. The large gerbil *Rhombomys opimus*. The Kyzyl Kum desert. Photo by I. S. Soldatkin.

Fig. 16. The Kara Kum sand desert in Turkmenia. Growths of saksaul. Burrow holes in a colony of large gerbils. Photo by P. A. Petrishcheva.




F i g. 17. The plan of a part of a colony of large gerbils. Turkmenia. Drawing by N. I. Latyshev and A. P. Kryukova, 1941.

are also used by man. Here on a path, the hungry ticks climb grass stalks and shrubs, usually not higher than one metre above ground, and assume an alert posture: clinging to a grass blade or a leaf they draw their front pair of legs wide apart and quickly attach themselves to the hair of passing animals or to a man's clothes.

Either foci (for size and extent) are elementary, if they ensure a continuous circulation of the agent of a transmissible disease, which is the basic factor of the existence of its focus.

A man or a susceptible animal attacked by infective vectors become ill if they have received an appropriate dose (amount) of virus infection. Small doses of certain viruses (for instance, tick-borne encephalitis virus), however, vaccinate man; he does not fall ill and acquires stable immunity, in the same way as artificial inoculation with the smallpox vaccine produces immunity lasting

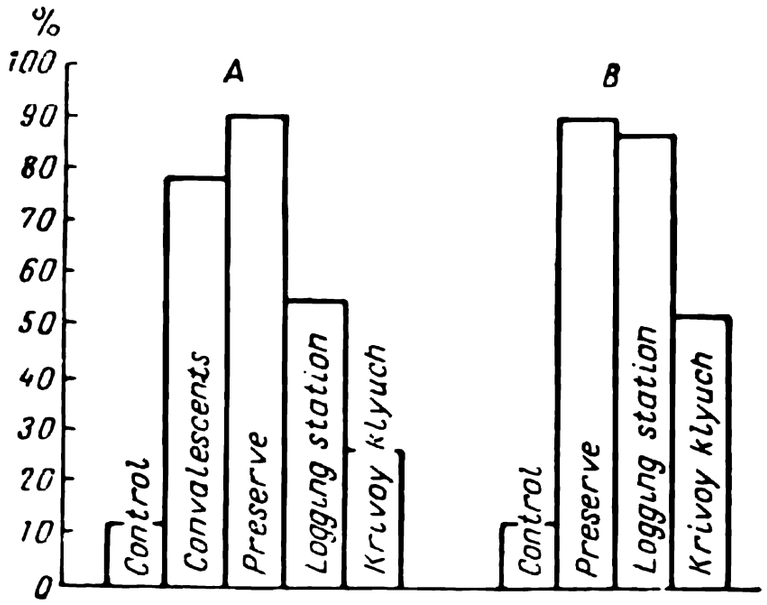
F i g. 18. A diffuse biotope of *Ixodes persulcatus*, *Haemaphysalis japonica* and *H. concinna* ticks in the taiga. Collection of ticks on gauze flags outside the Mountainous Taiga Station of the U.S.S.R. Academy of Sciences ("Krivoy Klyuch"). Working in overalls are G. S. Pervomaisky, A. N. Skrynnik and A. V. Kozlova (from left to right). Photo by A. V. Gutsevich.

for years. Therefore, the blood serum from a number of healthy persons is found to contain antibodies neutralizing in experimental conditions infection doses lethal for standard test animals. This phenomenon is observed in frequent contact of the population with the natural foci of a particular disease or during a more or less prolonged residence in the territory of or near a disease focus. It may also be observed in case of more or less frequent visits by people to territories with natural foci of disease. Cases are also known of a single visit by a non-immune man to a territory with natural foci of tick-borne encephalitis being followed by a disease with a fatal outcome.

Such "natural vaccination" of people points to the presence of a natural focus of disease in a particular area, even if it is still unidentified. Thus, a Czech complex expedition (B. Rosický et al.) to the west of the Balkan Peninsula found in the blood serum of certain healthy persons antibodies to West Nile encephalitis, which was a novelty for Europe in general. Yet the carriers of antibodies to this disease never suffered from it. In all probability, there is an unidentified natural focus of this viral disease in that locality. It is apparent that covert natural foci of West Nile encephalitis exist in certain localities, and people visiting them become immunized rather than ill.

The same is true for certain domestic animals, for instance, cattle, which are not liable to tick-borne encephalitis. It is even possible to trace an increase in the neutralizing power of their blood serum

Fig. 19. The forest litter under deciduous trees—diffuse winter dwelling of ticks. The Karelian Isthmus. Photo by N. D. Mitrofanova.




F i g. 20. The neutralizing activity of human blood serum (A) and cow blood serum (B) with regard to the virus of spring-summer encephalitis of human origin in the Suputin forest preserve, at the Mountainous Taiga Station of the U.S.S.R. Academy of Sciences and at a lumbering station. According to data by V. D. Solovyov (1941).

as long as they are in contact with natural foci of disease, i.e., stay in a territory with a natural focus of tick-borne encephalitis (forest pastures, Fig. 20). The same was found to be true for horses in Japanese encephalitis foci.

Consequently, natural foci of transmissible diseases may remain unidentified for an indefinitely long time. They are revealed when people non-immune to the agent of a given disease come to the territory of a latent focus.

A focus is latent during a season of prevalence of hungry, infective vectors, for instance, infective *Ixodes* ticks upon their hibernation.

Thus, the natural focus of a transmissible or parasitic disease is a biotope or a portion of the territory of a specific geographical landscape inhabited by a community of animals forming a biocoenosis; the specific and interspecific relationships between members of a biocoenosis ensure, given favourable micro- and macroclimatic conditions, a continuous circulation of a disease-producing agent among the members of the biocoenosis of a natural focus of disease. It is this continuity of circulation of an infective agent that sustains a natural focus (Fig. 8).

The term *focus* should be in general defined in greater detail on the example of tick-borne recurrent fever (spirochetosis or relapsing fever). It is known that cases of this disease are encountered in Central Asian towns; consequently, such a town may be rightly regarded as a focus of tick-borne relapsing fever. A detailed epide-

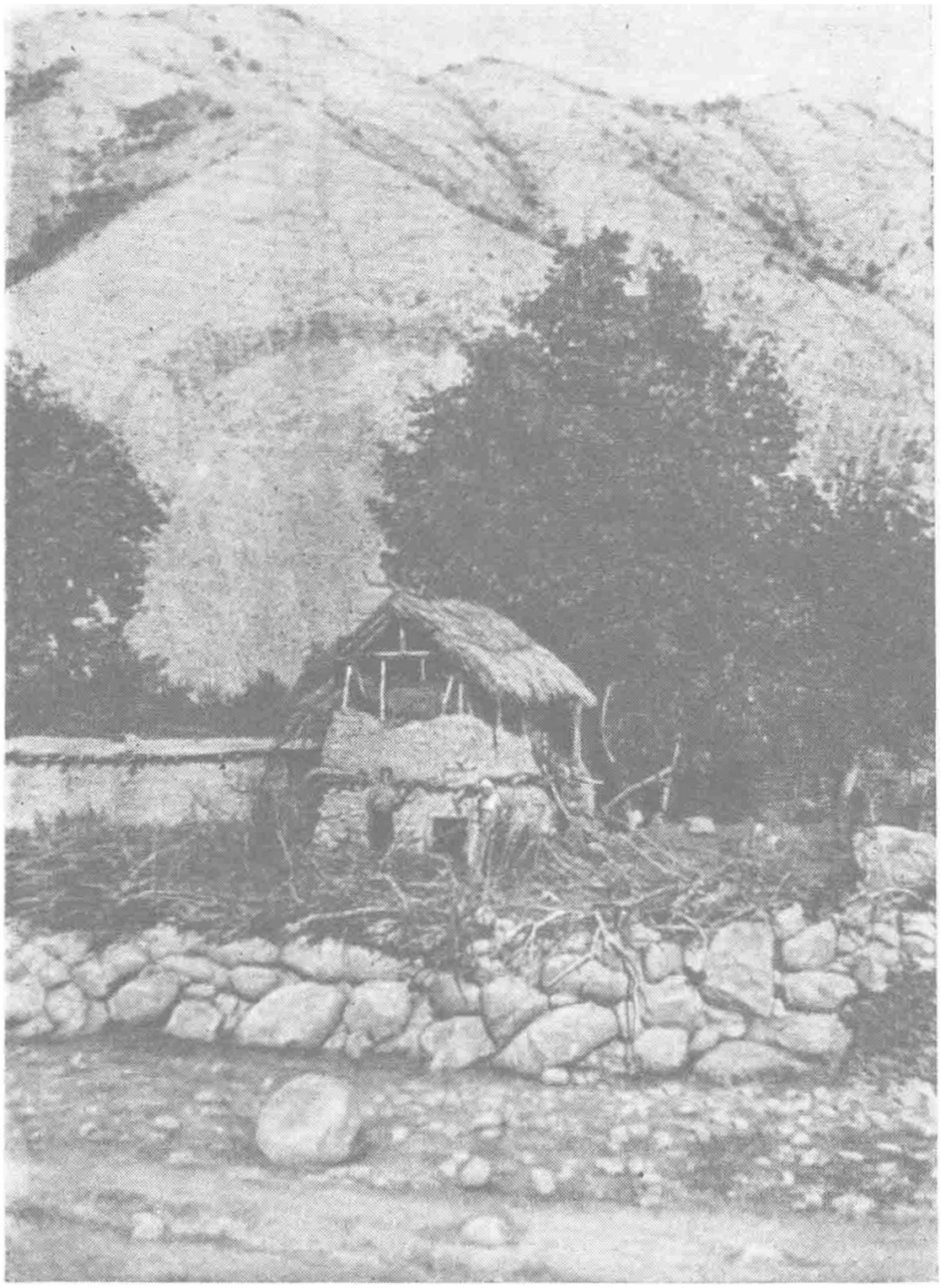


Fig. 21. A store shed for "saman" (adobe), a primitive structure in the Poguz village of the Varzob district in the Tadjik Republic—focus of tick-borne spirochetosis. Photo by Obidin (1939)

Fig. 22. A primitive building in a town of south-eastern Tadjikistan, converted in 1925 into lodgings for medical personnel. One of its rooms was repeatedly identified as a focus of tick-borne relapsing fever.

miological survey of such a focus of this disease shows that its incidence is the highest in town quarters with primitive old houses (Fig. 21), whereas in quarters with new European-type houses this disease is absent. It follows that the focus of this disease is confined to definite parts of the town.

When in the 'thirties medical aid became for the first time available in out-of-the-way villages of Central Asia, local dwellings had to be adapted for the first hospitals and dormitories for medical personnel (Fig. 22). In one of such dormitories tick-borne relapsing fever was contracted by occupants of a particular room, whereas their neighbours living in another room of the same house remained healthy. Convalescents moved to another apartment, and their former dwelling was taken by newcomers some of whom later became ill with the fever, while their neighbours remained as healthy as before.

Consequently, the focus of this disease was a definite room in a definite house of a definite village quarter.

What is the reason for this fractional character of the concept of a "tick-borne relapsing fever"? It was the fact that this focus—a room—had burrows of the Turkestan rat which may acquire the causal agent of tick-borne relapsing fever and contain it in its blood for some time. The rat burrows (in the room in question) were inhabited by tick vectors (*Ornithodoros papillipes*) * which fed on the

* According to priority rules, the correct spelling is *Ornithodoros*, but many prefer to spell it *Ornithodorus*.

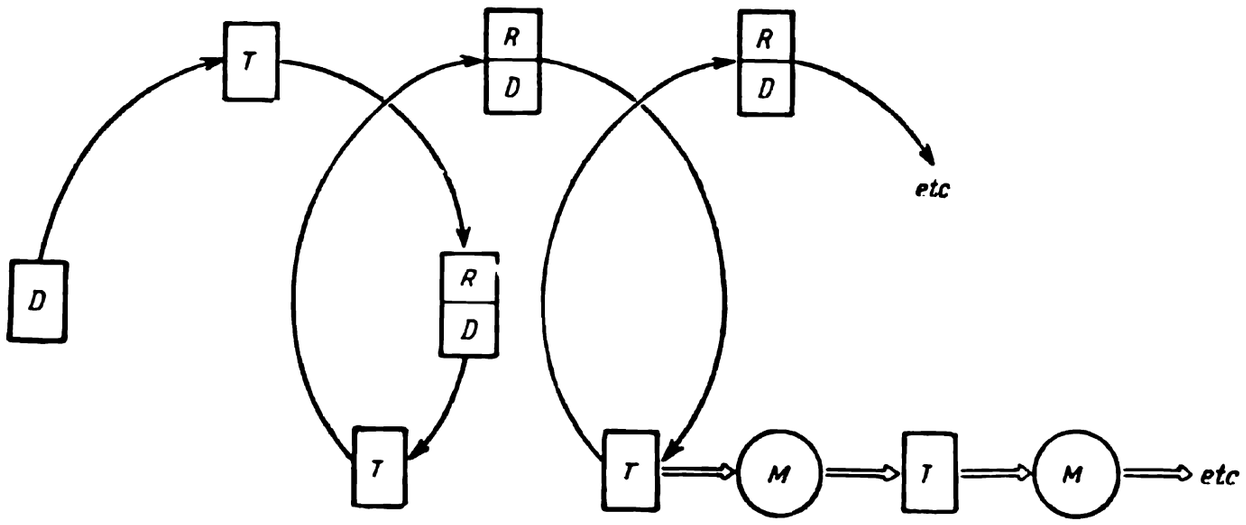



Fig. 23. Diagram showing circulation of tick-borne relapsing fever spirochetes in a natural focus of this disease and extension of this focus to a human habitation. According to E. N. Pavlovsky.

D—animal donor of spirochetes; T—*Ornithodoros papillipes* ticks—vectors of spirochetes; RD—animal recipients of the pathogenic agent becoming during spirochetemia donors of the pathogenic agent to susceptible animals (RD) or to man (M) who becomes a donor of spirochetes by the route M—T—M—T.

blood of the burrow hosts. These ticks become vectors of infection for a rats' progeny and for people living in the tick-infested room, if the ticks climb out of a burrow and attack a man sleeping near-by. Their bites are painless for man, he is unaware of them in his sleep and so contracts the infection.

Tick vectors can starve for a long time, even for years, in the absence of prey (if such a room is vacated or if the rat hosts of the burrows die from a certain cause). The ticks remain in the empty burrow, abstaining from migration to another room. When the latter is taken by new residents, the ticks attack them and infect them with relapsing fever. *The focus of this disease is, in effect, the rat burrow*; the biocoenosis of such a biotope as the burrow includes tick vectors (*Ornithodoros papillipes*) which remain capable of transmitting relapsing fever spirochetes contained in them even after 11 years' starving, as has been found by E. N. Pavlovsky and A. N. Skrynnik. Even when starved, these ticks do not seek another burrow or room, which fact accounts for such a close relationship between a disease focus and a particular room.

In a hospital housed at first in a somewhat modernized primitive building, physicians happened to find tick vectors of spirochetosis even on the walls of a ward.

Tick-borne spirochetosis is such a disease basically occurring in natural foci, which an ill man can communicate to other *Ornithodoros papillipes* ticks (Fig. 23,M), and the latter in their turn transmit spirochetes to other persons.

## VECTORS OF TRANSMISSIBLE DISEASES WITH NATURAL FOCI, THEIR BEHAVIOUR AND ENVIRONMENTAL FACTORS INFLUENCING THEIR AGGRESSIVENESS

When biting an animal or man ticks and insects usually implant the disease-producing agent contained in their salivary fluid into the blood of the recipient if they themselves are in an infective state, and the recipient thus contracts an infection.

The consequences of such an infection for man depend on the following factors: (1) *the pathogenicity* of the disease-producing agent as its general specific property; (2) the aggressiveness of vectors and the infection dosage; (3) *the degree* of virulence of the disease-producing agent; this degree depends on the physiological state of the agent and on the joint influence exerted on it by many factors during its presence in the vector's system (for instance, the environmental factors: temperature, etc.); the variability of the agent's properties depends on the preceding routes of circulation of its strain * (Fig. 23), which may have earlier passed through the bodies of various species of mammals, birds, and reptiles; (4) the individual state of the vector, man and recipient animal; for example, in the presence of definite combinations of environmental factors the behaviour of the vector may change and, though being hungry, it will not attack man or animals.

Thus, in Southern Tadjikistan, Prof. A. S. Monchadsky and his associates studied a relative prevalence of mosquitoes and detected species usually attacking man at dusk and at night. It is in these hours that people contract malaria. Simultaneously, records were taken of calendar dates (month, days), observation hours, and weather conditions (temperature, illumination, wind force, humidity). Such observations were repeated many times in different months, days, and hours of day and night. It was found that at the end of summer, with a certain combination of weather conditions, the hungry malarial mosquito females, which are the very individuals that feed on human blood, do not attack man in certain hours of the day although they have every chance to do so. Consequently, under specific conditions, the hours of the day when man is most likely to contract malaria become practically safe, though only in the presence of a certain combination of weather conditions prevailing at the time, whereas at another time and with a different weather things may take a different turn.

When it rains mosquitoes do not attack man and animals in the open air. Smaller bloodsucking insects known as midges fly in the air when it drizzles. Larger bloodsucking insects—horse flies—attack man in the open air during the hot hours of the day; if at

* The strain—subsequent generations (or "pure lineage") from the culture of a disease-producing agent isolated under definite conditions and supported by reinoculation on nutrient media or passed through laboratory animals.

Fig. 24. Reclamation work on hillsides in the Far East. A forest landscape, the habitat of *Ixodes persulcatus* ticks, vectors of tick-borne encephalitis, being reclaimed for a vegetable garden. Photo by G. V. Serdyukova.

this time they invade a house they gather together near sunlit windows and do not attack humans in the room.

Mosquitoes behave differently. Their females bite man within houses, too. Engorged females leave the house and head for the nearest water reservoir to lay eggs. There is a group of horse flies which also attack man during a rain if it is not too heavy, and are therefore called rain breeze flies.

Certain bloodsucking flies are associated with definite hosts: for instance, the horse fly (*Hippobosca equina*), the horn fly (*Lyperosia irritans*), which is parasitic on cows, the wingless sheep tick (*Melophagus ovinus*) which has lost its wings in the process of its evolution and is parasitic on sheep, etc. These selective parasite-host relationships make insect vectors liable to transmit agents of diseases specific of their hosts.

Diseases with natural foci affecting both animals and man belong to the group of zooanthroponoses. Different species of wild beasts of one and the same biocoenosis or one and the same genus may, other things being equal, have a different susceptibility to the agent of one and the same disease.

The natural foci of certain diseases are characterized by the fact that crawling and long-biting vectors can acquire infection exclusively from wild animal donors and are practically unable to receive it from man; this is the case, for example, with the natural foci of tick-borne encephalitis and tick-borne rickettsiosis.

The reason is that a hungry *Ixodes* tick attaching itself to the human body will inflate with blood during its blood meal which lasts for a few days, and will be noticed and removed. Even if it is fortunate to engorge itself and fall off its prey of its free will it will be unable to produce offspring in a human dwelling, since vectors of such diseases as tick-borne rickettsiosis, encephalitis, etc., cannot become habituated to human surroundings.

In such cases, general amelioration of a locality results, as a rule, in a gradual extinction of natural foci, for instance, of tick-borne encephalitis (Fig. 24).

Vectors of other transmissible diseases may, on the contrary, easily adapt themselves to a new environment in close proximity to man whom they repeatedly attack and infect with a disease, which is subsequently taken up by other vectors (for instance, mosquitoes transmitting yellow fever virus, certain *Argas* ticks of the genus *Ornithodoros*—vectors of tick-borne spirochetoses).

It may also happen that a human dwelling and outbuildings (especially in a wild country, for instance in a semi-desert or desert) are also infested by donors of a disease with natural foci, which are typical representatives of the wild fauna, as the gerbil in Central Asia.

All this gives rise to daughter foci of disease formed by extension or *radiation* from a major focus. In new surroundings such new foci may become firmly implanted for a long time (for example, tick-borne relapsing fever in villages infested by *Ornithodoros papillipes* tick vectors).

## CHAPTER II

# CAUSATIVE AGENTS OF DISEASES WITH NATURAL FOCI

The causative agents of diseases with natural foci are quite variable. Most of them are microorganisms of vegetable origin—rickettsiae, spirochetes, bacteria, fungi and are, as a rule, of a microscopic size; yet there are pathogenic agents which are invisible through a common microscope in passing light even at the largest magnification. Such agents are known as viruses or filtrable viruses, so called because they can pass through the pores of a porcelain filter, retaining their virulence. Electron microscopy with a magnifying power of tens and hundreds of thousands of times reveals elementary bodies whose size is measured in fractions of a micron.

Viruses may cause diseases of plants (for instance, tobacco, whose virus was discovered by D. I. Ivanovsky), animals, and man.

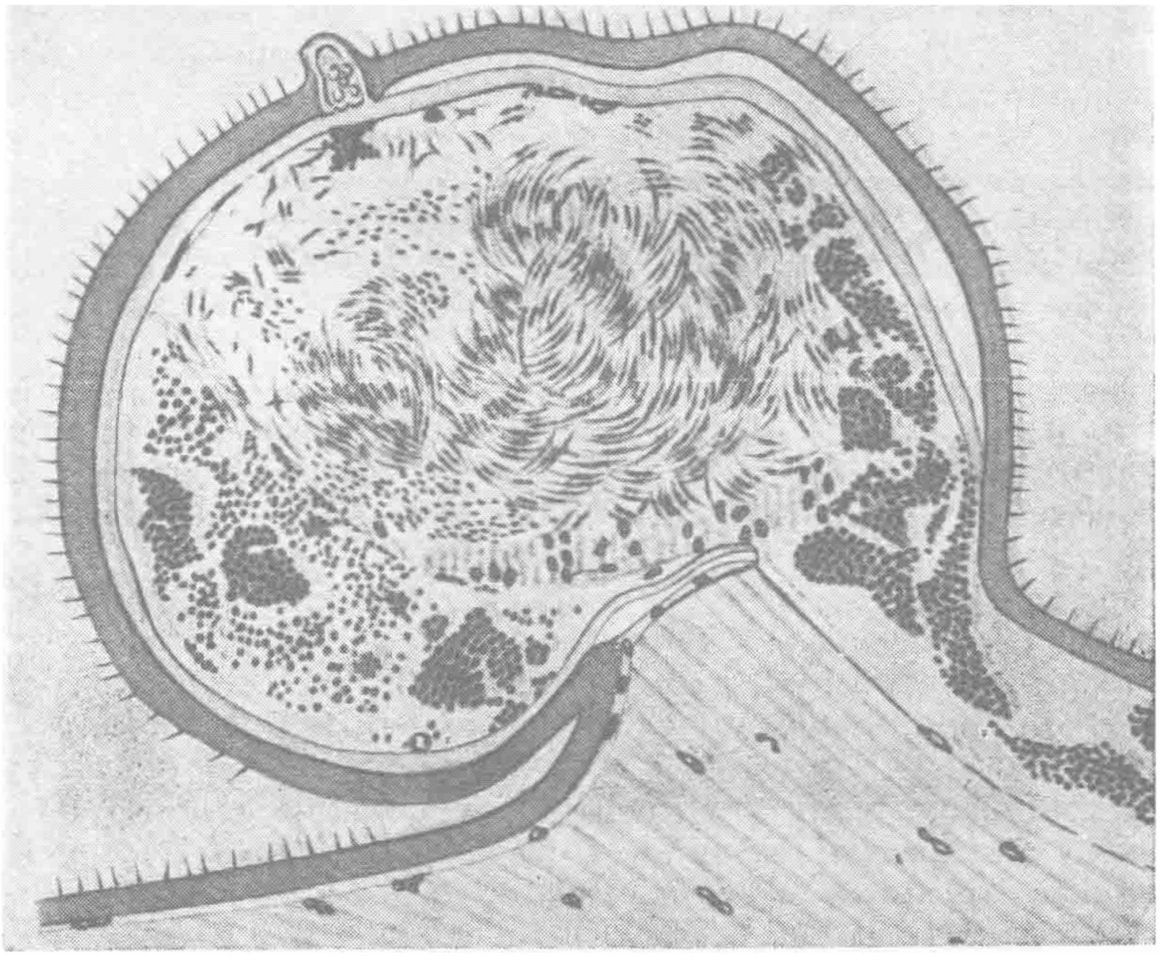
In our further discussion of the problem of disease-producing agents, we shall refer to them as to microbes in general. Various protozoa of animal origin may also produce a disease.

Many of the disease-producing agents inhabit exclusively the vector body or the organism to which they are transmitted by vectors. Therefore, disease-producing agents should be discussed bearing in mind their close association with vectors and those organisms in which they cause one disease or another.

The agents of certain diseases can live in the external environment and are subject to special discussion.

## CIRCULATION OF A CAUSATIVE AGENT IN THE VECTOR BODY

A microorganism which has entered a vector's body through a certain portal of entry (for instance, through the sucking mouth parts into the stomach) reaches the exit from the vector, for example, the malarial parasite arrives at the salivary glands of the female



F i g. 25. The sporozoites of the Plasmodium malariae in the body cavity of the *Anopheles* mosquito—vector of malaria. Cross-section according to Muelens.

*Anopheles* mosquito, the specific vector of malaria. When subsequently drawing blood the female anopheles punctures the human skin with its proboscis and simultaneously discharges its salivary fluid which causes a painful sensation once it has got under the skin. If the salivary fluid of such a mosquito contains malarial organisms in the form of microscopic sporozoites the latter are inoculated with the fluid into the human body and produce malaria.

For a malarial agent which has gained entry into the mosquito body, to reach the exit, it has to travel the route from the stomach to the salivary glands.

The complexity of this process in the body of the female anopheles consists in that the malarial plasmodium in the process of sexual reproduction penetrates the stomach wall to its outer surface where it forms oocysts. Here, as a result of division in the oocysts sporozoites multiply in great numbers, burst the oocyst wall, and invade the mosquito body cavity (coelom) (Fig. 25) and then are carried by the hemolymph to the salivary glands, penetrate them, invade their cells and during a discharge of salivary fluid find themselves in the salivary gland duct opening out into the sting known as the

hypopharynx; the latter has a canal passing all along its length through which the salivary fluid containing infective malarial plasmodium forms (sporozoites) is inoculated into the human skin. In this way, the malarial agent, entering the mosquito stomach through an entry-way formed by the sting canal and esophagus, reaches the exit, i.e., the salivary glands and their duct, *having passed through the mosquito body cavity*. This form of circulation of the malarial plasmodium is called *metacoelomic* (*transcavitary*).

The mosquito has not its own body temperature and in this respect entirely depends on the environmental temperature: in winter, when it finds shelter in secluded places, for instance, cellars, it becomes torpid and with the coming of a warm weather recovers from its lethargy and regains its activity.

The malarial parasites can multiply within the mosquito body at a temperature of not lower than 15-16° C. This illustrates the effect of temperature as an environmental factor on a malaria-infected mosquito and through the medium of its body on the pathogenic agent.

The influence of the environmental temperature on the transmission by an infective mosquito of the virus of another transmissible disease—pappataci fever—is illustrated by experiments which have been carried out in Britain. When mosquitoes were fed on human subjects at an external temperature of 18.5° C these subjects became ill, whereas no disease was observed when the insects were fed at a temperature of 15° C (Whittingham, cited from Petrov, 1929, p. 13). A mosquito engorged with blood from a sick donor transmits the virus to a healthy person not immediately but in 6-8 days, time required for the virus to reach the exit from the mosquito body and make the latter infective.

The causative agents of certain transmissible diseases are differently influenced by temperature changes. Various species of mosquito vectors of the virus of yellow fever, a virulent tropical disease, exert a variable influence on this virus in an experiment; for example, a mosquito engorged with human blood containing yellow fever virus transmits it to a healthy subject after a period of several days. The duration of this period fully depends on the air temperature. Hindle's and Davis's experiments have proved that at 37° C this period is the shortest, lasting only 4 days, whereas at 21° C it continues as long as 18 days. At 16° C, however, this virus fails to produce a fatal disease in infected animals.

The reaction of certain insects to environmental changes may be delicate and immediate and influence their general behaviour (degree of aggressiveness) as far as their proneness to attack man and animals is concerned.

In this connection it would be in point to describe the results of observations of mosquitoes' behaviour during the solar eclipse

on June 19, 1936. At the observation post (Tsugulovsky Datsan) the eclipse was not total; without a large risk of error it could be assumed that at this point the extent of the greatest phase of the eclipse was the same as in Chita, i.e., 0.94 (according to the bulletin issued by the preparatory commission for the study of the solar eclipse). The observations were carried out on the banks of the Onon River. The first batch of mosquitoes were captured before the onset of the eclipse, the second—during its maximum phase, and the third—at the time when the intensity of illumination began to grow. Each time, the insects were captured by four researchers on themselves simultaneously during 10 minutes.

At the initial period of the eclipse, when no sharp decline of illumination had yet occurred, no changes were noted in the behaviour of bloodsucking dipterans. When it had noticeably grown dark, however, mosquitoes became more active, they were flying about excitedly and attacking en masse. Individual black flies and midges also appeared. This activity continued for about 15-20 minutes, and, when it began to grow light, noticeably decreased. The count of the captured mosquitoes makes it possible to illustrate what has been said above by figures. In the first bout, 38 insects were captured (exclusively *Aëdes caspius* mosquitoes), in the second time 55 (including 3 black flies *Simulium cholodkovskii* and one midge *Culicoides nubeculosus*; the rest were *Aëdes caspius* mosquitoes), at the third time 42 (exclusively *Aë. caspius*). Figures show a noticeable, approximately 50 per cent increase in the numbers of attacking diptera at the moment of the maximum obscuration. This may have been partly due to the rapid increase in the relative air humidity from 34 per cent during the first capture to 60 per cent at the maximum phase of the eclipse (Gutsevich et al., 1939).

The behaviour of mosquitoes is also influenced by the lunar phases, which cause a change in the frequency of night attacks, the terms of swarming, and, apparently, in the rates of invasion of enclosed premises. The regularity of these periodic changes suggests an important conclusion concerning epidemiological deviations in the lunar month (Monchadsky, 1953, 1956).

The above examples illustrate the influence which may be exerted on the appearance of transmissible diseases by the environment whose factors produce a variable effect on the vectors spreading the infection.

The aforesaid gives one reason to consider that the natural foci of diseases are certain territories inhabited by wild animals liable to become affected with diseases which, through the agency of bloodsucking insects and ticks existing in the same place, are transmitted from the animal donor to other animals and man unless *variations of the climatic factors of the environment interfere with such transmission.*

## THE MODES (MECHANISM) OF TRANSMISSION OF PATHOGENIC AGENTS BY THEIR VECTORS

The transmission of a pathogenic agent by a vector to man is accomplished only after the agent has reached the exit from the vector, which makes the latter capable of infecting. The route by which the agent travels from the stomach to the salivary glands of the *Anopheles* mosquito is complicated, as has been described above.

In other species of vectors and with other pathogenic agents this route may be simple or even direct.

The *metacoelomic* route lying through the body cavity of tick vectors is traversed by the following pathogenic agents: the tick-borne encephalitis virus, the agents of tick-borne spirochetoses of man, animals and birds.

There are other vectors, however, whose coelom the pathogenic agents do not enter, remaining all the time within the digestive organs. In all cases, the pathogenic agent enters the vector by the mouth and leaves it by the anus. Such passage (and transmission) of the pathogenic agent is known as through passage (*oro-anal, through, fecal transmission*), e.g., of *Trypanosoma cruzi*, the causative agent of Chagas' disease of South America transmitted by the bug *Triatoma megista* (*Conorrhinus megistus*), family *Reduviidae* (Fig. 26).

The transmission of *Trypanosoma grayi*, a blood parasite of large reptiles, by the bloodsucking *Glossina* fly is somewhat complicated. Trypanosomes entering the stomach pass into the small intestine of the fly. The stomach and intestine of the fly are lined on the inside with the peritrophic membrane which becomes detached from the stomach and intestinal epithelium and looks like a cylinder inserted into the stomach and intestine. The posterior end of this cylindrical membrane is open, therefore, trypanosomes come out through this end and penetrate by a reverse motion into the fissure between the intestinal epithelium and the membrane. Finally, they concentrate between the peritrophic membrane and the hindgut epithelium and are expelled with feces in an infective state. This circulation of trypanosomes (*T. grayi*) in the *Glossina* fly is also a through passage via the fly's alimentary canal, though complicated in consequence of trypanosomes entering under the peritrophic membrane of the hindgut and being discharged with feces through the anus; if the *Glossina* fly discharges its feces on the body of its temporary host, the latter will sustain fecal contamination (Fig. 25).

The trypanosoma *T. gambiense*, causing sleeping sickness of man in Africa, undergoes the most intricate process of circulation in the body of its carrier—the tsetse fly (*Glossina palpalis*). After the fly has bitten a patient with sleeping sickness, trypanosomes get into its stomach, but it is only the short forms of trypanosoma that undergo further development and circulation associated with it. They concentrate in the posterior part of the fly stomach, where

by the 10-12th day after it has bitten a sick man many slender trypanosomes appear. Moving in the reverse direction they pass from the stomach into the foregut and between the 12th and 20th days they transform into the so-called *crithidial forms*; the latter, through the esophagus and oral orifice find their way into the proboscis and via the salivary duct penetrate into the salivary glands of the tsetse fly. Having settled on the inner surface of the glands the crithidia multiply by fission generating the metacyclic (final) form of trypanosomes infective to man. When a tsetse fly in this condition bites a man, *metacyclic* trypanosomes are washed out with the stream of salivary fluid and with it are inoculated into the skin, infecting man with sleeping sickness (Fig. 26).

*This is direct evidence of gastro-salivo-glandular reverse transmission by inoculation of the sleeping sickness agent. In this type of transmission the cycle of the development and reproduction of trypanosomes is confined to the alimentary tract of the tsetse fly, and it takes a certain time before trypanosomes become infective.* This form of transmission is known as the *cyclopropagative* form, inasmuch as trypanosomes change in accordance with their propagation cycles, but these cyclic changes are slight.

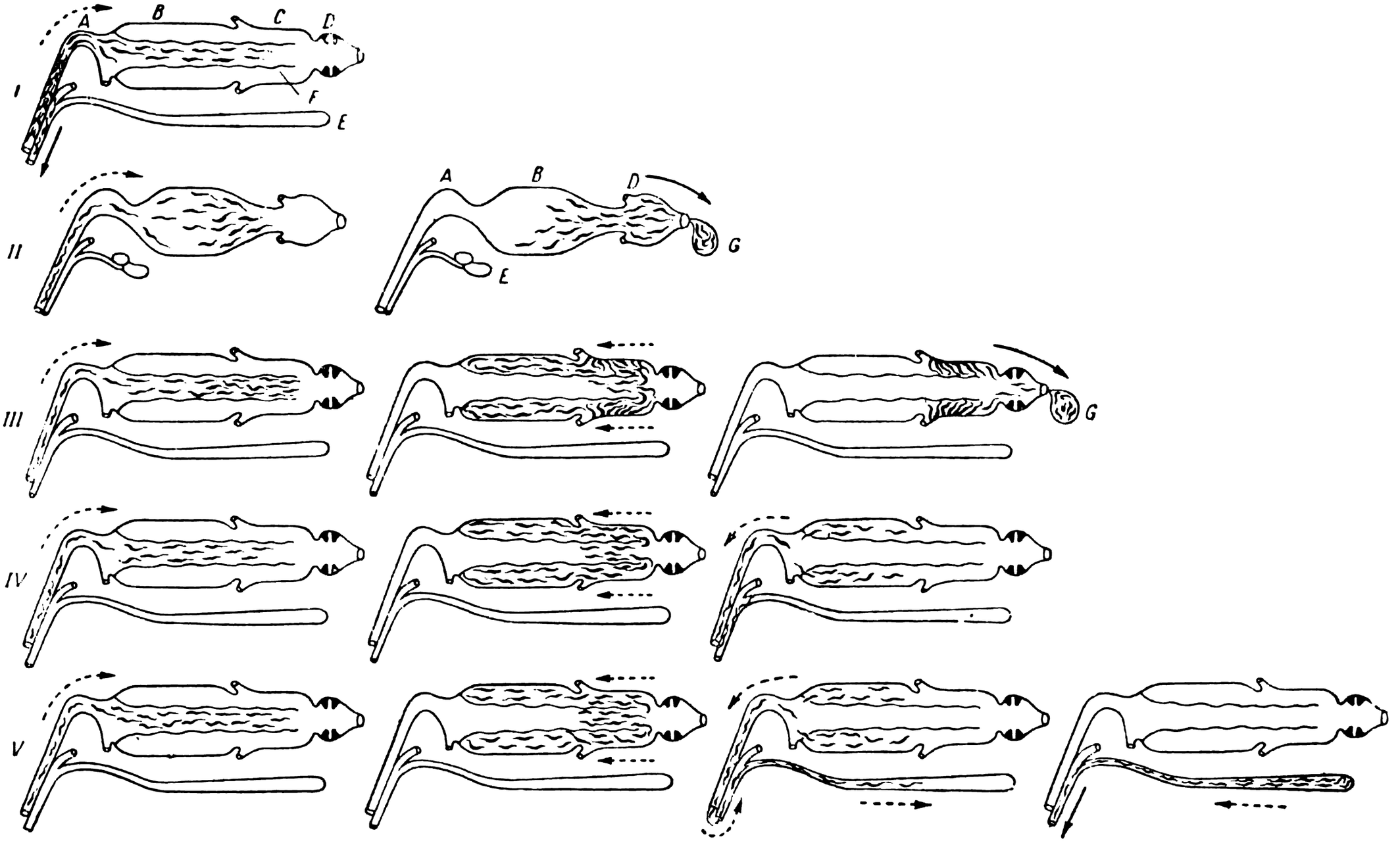
Such a tsetse fly remains infective through life. It has been found in experiments on various animals that not every tsetse fly which has ingested blood containing trypanosomes becomes infective, and the infection rates in the *Glossina* fly are 10 per cent at the most (Geigy and Herbig, 1955, p. 232). In like manner, develop other trypanosomes of the *Brucei* group: *T. brucei*, the cause of the disease called nagana of cattle and *T. rhodesiense* which along with *T. gambiense* is the cause of human sleeping sickness of Africa, but *T. gambiense* causes sleeping sickness prevailing in the western and central areas, and *T. rhodesiense* in the eastern areas.

The difference between the aforesaid processes and the transmission of malaria by the *Anopheles* mosquito consists in that the sleeping sickness trypanosomes do not leave the stomach for the vector body cavity but stay all the time within the alimentary tract of the fly and by reverse motion penetrate into its salivary glands and are inoculated with the salivary fluid into the human skin.

The behaviour of the spotted fever agent in its vectors—the head and body lice—is simpler. Spotted fever is caused by microorganisms known as *Rickettsiae prowazeki*, the name they take from Ricketts and Prowazek who died of this disease during a study of *Rickettsia* organisms.

Patients with spotted fever have rose rash on the skin. The endothelial cells lining the subcutaneous capillaries proliferate in these regions. *Rickettsia* organisms multiply in the cell protoplasm on a mass scale, causing the cells to swell.

The louse ingests blood containing *Rickettsia* organisms which penetrate into the protoplasm of its stomach cells and quickly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multiply there. The affected cells grow in size, parts of the protoplasm filled with *Rickettsia* organisms breaking off and entering the stomach cavity. When passing further into the intestine these parts mix with the louse feces.

The louse excretes rickettsia-infected feces. In such cases, the pathogenic agent also follows a through (but direct) route: the esophageal orifice of the louse serves as the portal of entry, the anal orifice as the exit. Along this route, *Rickettsia* organisms multiply in the stomach epithelium.

Man is infected with spotted fever in consequence of his body being contaminated with louse feces containing *Rickettsia* organisms. When scratching himself to relieve the itching caused by louse bites man is likely to damage his skin thereby letting *Rickettsia* organisms into his body.

The propagation of *Rickettsia* organisms within the louse stomach epithelium, their entry into the stomach lumen together with the detached portions of the affected epithelial cells and their expulsion with feces—all this taken together is a simple form of specific relationships between the pathogenic agent and its vector.

This form of transmission of disease is known as *propagative contamination.*

The common feature of the above-described modes of transmission of trypanosomes by tsetse flies and of *Rickettsia* organisms by lice is the fact that neither trypanosomes nor *Rickettsia* organisms penetrate into the vector body cavity during their reproduction but stay all the time within the alimentary organs of their respective vectors.

In other words, no *transcavitary migration of pathogenic agents* takes place in such vectors.

The mode of transmission of dengue fever virus is different. It is transmitted by *Aëdes aegypti* mosquitoes (*Aë. argenteus*) in two forms

◀Fig. 26. Trypanosoma cycle and its evolution in tsetse flies (*I*, *III*, *IV*, *V*) and in the *Conorrhinus* bug (*II*). According to Geigy and Herbig, 1955.

*A*—esophagus; *B*—stomach; *C*—hindgut; *D*—rectal sac; *E*—salivary gland; *F*—peritrophic membrane; *G*—drop of feces. The dot-line arrow shows the route of entry of trypanosomes and their migration in the alimentary canal of *Glossinae*; the continuous arrow indicates the route of exit of infective trypanosomes from the vector. The Malpighian vessels are shown only in sections at their portal of entry into the hindgut; they take no part either in the migration or in the exit of trypanosomes. *I*—*Trypanosoma vivax* from the tube of the peritrophic membrane do not pass into the hindgut, part of them enter the outlet portion of the salivary glands from where they are washed out with the salivary fluid; *II*—*T. cruzi* in the intestine of the *Conorrhinus* (*Reduviidae*) bug; trypanosomes pass through the alimentary canal, by-passing the salivary glands, and are eliminated with feces through the anus; *III*—*T. grayi*: trypanosomes from the tube of the peritrophic membrane pass into the space between it and the epithelial lining of the stomach, concentrate in the hindgut and are discharged with feces (drawing at extreme right); *IV*—*T. congolense*: the same route of migration but trypanosomes from the perimembranous space move forward in the reverse order, penetrate through the anterior viscid portion of the membrane into the proboscis, pass into the common duct of the salivary glands from where to be washed out with the salivary fluid; *V*—*T. brucei*, *T. rhodesiense*, *T. gambiense*: trypanosomes enter the stomach by the same route, but all of them pass back from under the peritrophic membrane into the proboscis, enter the salivary glands and fill them all along their length and are washed out as infective forms with the salivary fluid.

and two stages: (1) by means of contaminative inoculation, i.e., mechanically, in consequence of the virus being preserved for one to three days in the mosquito's mouth parts following its blood meal on a sick person; (2) by ingestion of blood containing virus which for at least eleven days circulates in the mosquito body, finally reaching the exit at the mouth parts of the mosquito. In this, second tour, the same *Aë. aegypti* mosquito (*Aë. argenteus*) now represents the specific vector of the dengue fever virus. Data on the ecology of dengue fever have been furnished in Wisseman and Sveet's paper (1961) together with a chart of the world prevalence rates of dengue fever virus (with reference to places of its isolation), the *Aëdes* mosquitoes—vectors of dengue fever virus, and of the geographical points where antibodies to this virus have been discovered in the human blood.

One may ask whether vertebrates, for instance, mammals, can be vectors of any disease-producing agents, meaning the infection transmission process as such. Indeed, they can, though very rarely, and only as far as certain species are concerned. In particular, one might refer to a bloodsucking mammal, for example, the South American chiropteran vampire (*Desmodus rotundus*) which feeds on the blood of mammals including monkeys. If it happens to bite a monkey affected with yellow fever the virus remains in its mouth for a very short time. Once its blood meal has been interrupted, a vampire may bite another, healthy monkey in a minute's time and impregnate it with yellow fever virus *.

In this way, the vampire may be a specific vector of yellow fever virus (Kumm, 1932).

## THE FATE OF THE PATHOGENIC AGENT (MICROBE) IN THE BLOODSUCKING ARTHROPOD VECTOR AND CUL-DE-SACS IN ITS CIRCULATION

The blood of a viruliferous animal donor or an animal harbouring pathogenic bacteria is a nutriment for a multitude of bloodsucking arthropods: mosquitoes, horse flies, black flies, midges, *Ixodes* ticks, etc. If a blood meal takes place during virusemia, i.e., when a virus or other pathogenic agent is present in the donor blood, the pathogenic agent will enter the alimentary tract of a particular arthropod engorged with the donor's blood. It is only the specific vectors of a given pathogenic agent, however, that can subsequently transmit it to a recipient, for instance, *Ixodes persulcatus*, *I. ricinus*, *Dermacentor silvarum*, *Haemaphysalis concinna*, etc., transmitting the tick-borne encephalitis virus. It is apparent that in the

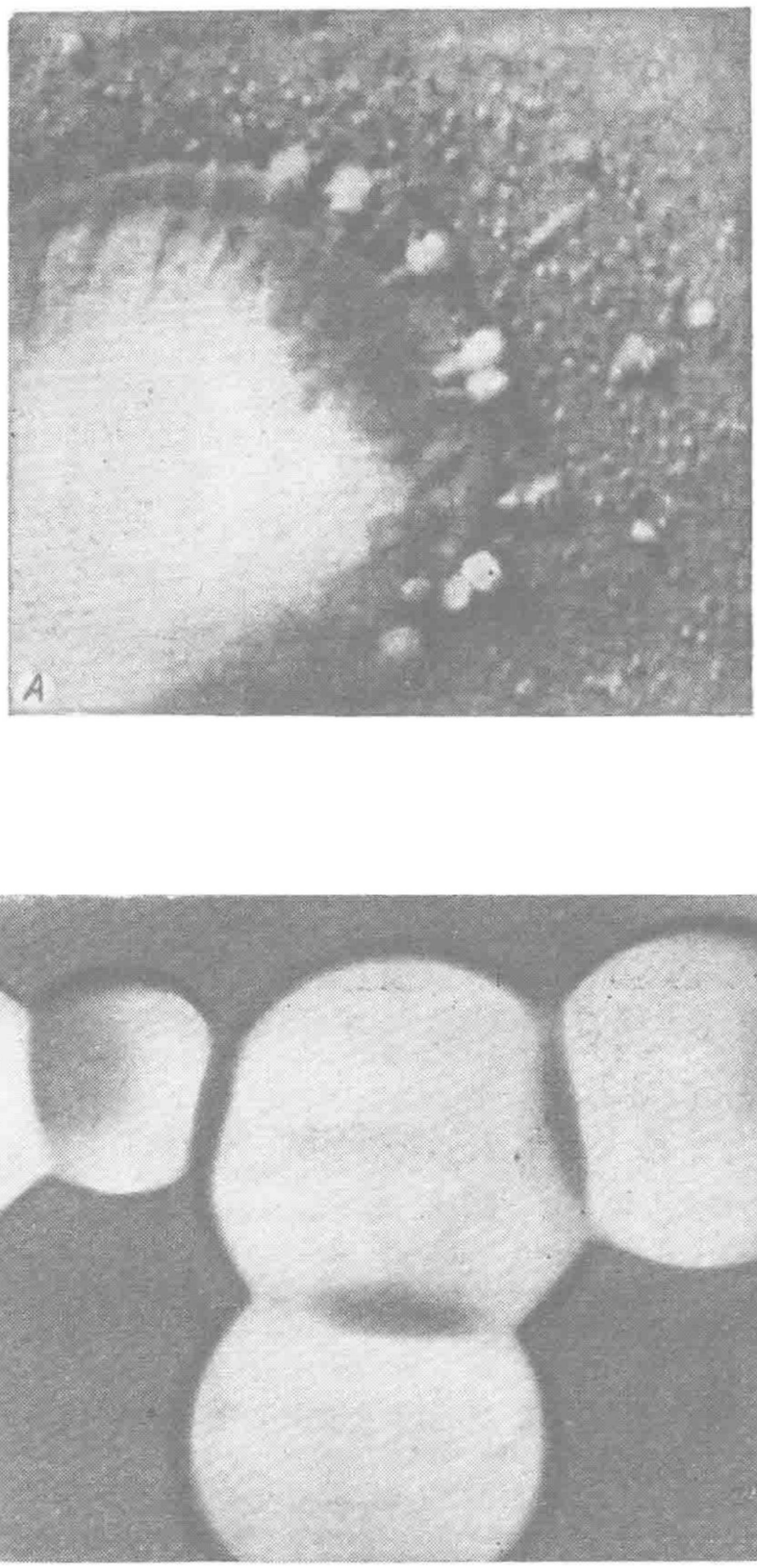
* An interesting paper on vampires as vectors of trypanosomoses of South American ungulates was published in Russia by S. A. Goar in 1962.

Fig. 27. A phage. The round bodies with processes. Electron microscopy. According to M. V. Pospelova.

bodies of these tick species the pathogenic agent will fortunately pass the intestinal barrier with its characteristic enzymes; the tick intestine may also contain bactericidal substances or special phages capable of destroying a given type of pathogenic agent by lysis (Figs. 27, 28).

If the pathogenic agent has fortunately negotiated the intestinal barrier and reached safety in the vector body cavity it will find another habitat there, with new dangers, for example, the hemolymph phagocytes. Moreover, the pathogen has to reach the exit from the vector body, which not every type of pathogen is capable of. For example, Obermeier's spirochetes are unable to get out of the louse body cavity by themselves and remain hopelessly shut in within it. They are freed from their confinement only after the louse has been crushed, which is an artificial factor of transmission (such form of infection transmission is known as *grattage* *) (Fig. 29).

* *Grattage* (Fr.)—scratching; here implies crushing of the louse.




F i g. 28. Destruction of bacteria by a phage. According to Herčik.
*A*—adsorption (fixation) of phage on bacteria; *B*—brucellae.

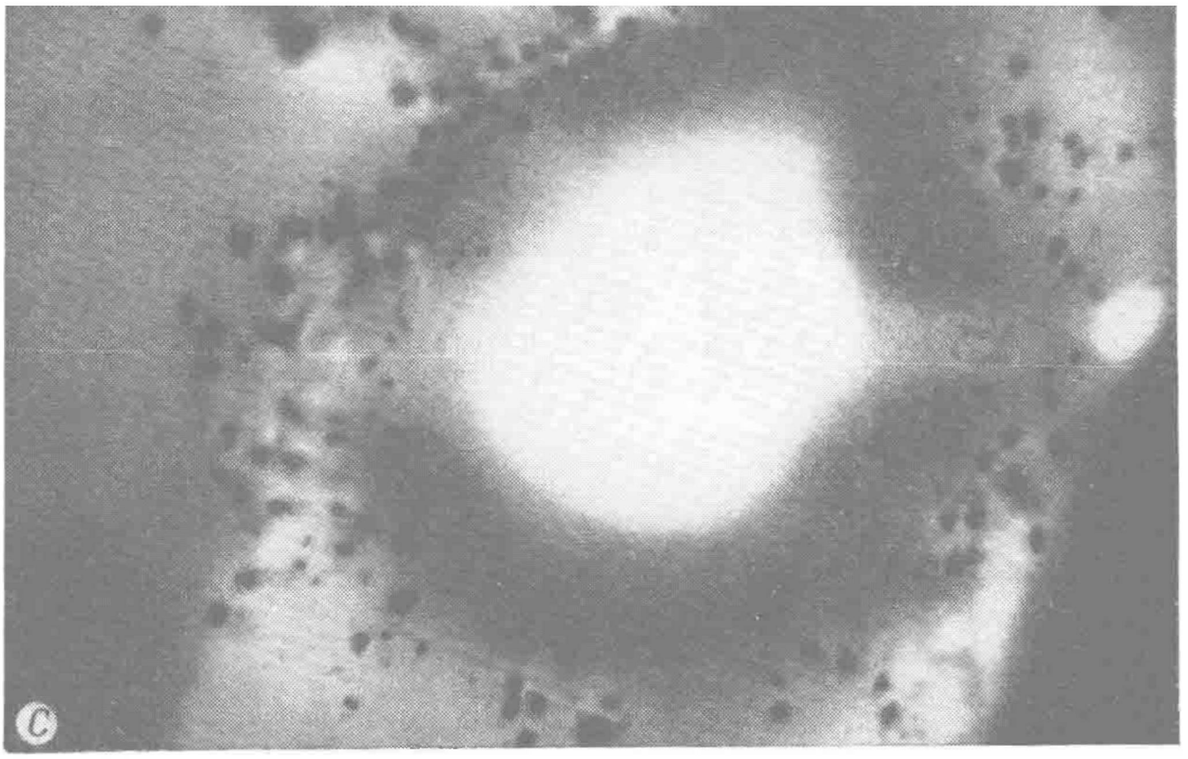
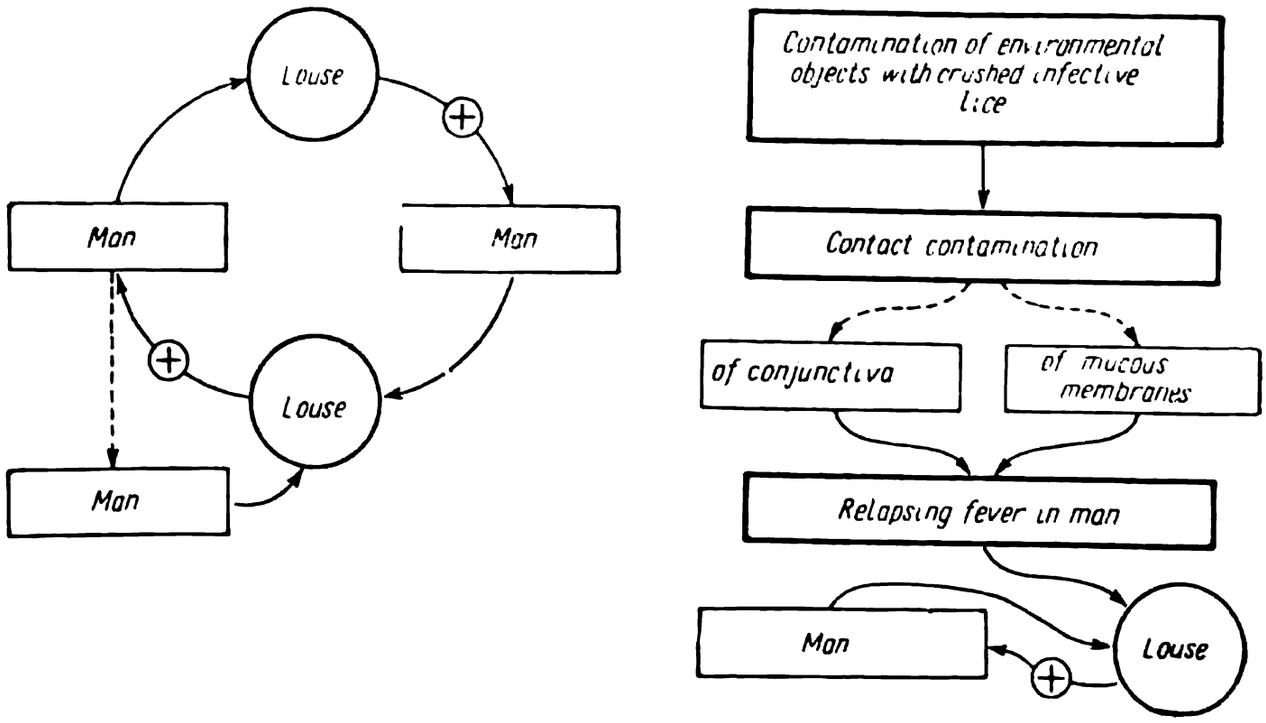


Fig. 28 (continued).
*C*—destruction of brucella by phage (*B* and *C*—ultramicrophotographs).

The matter is even more intricate when a microbe is implanted into the gut of an insect undergoing complete metamorphosis, for instance, the common house fly. Indeed the imago fly, its crawling larvae and immobile pupae present quite different habitats for an ingested bacterium, the more so, as in the pupal stage there occurs disintegration of the larval organs and formation of new organs. What is more, there is a marked difference between the mode of nutrition and life of imago flies and that of their larvae. Nevertheless, certain bacteria, for instance, *Bacillus pyocyaneus*, survive through the complete metamorphosis of the common house fly (Bacot, 1914).

Experimenting with the feeding of the flour beetle (*Tenebrio molitor*) on tuberculosis bacteria, one can see that the latter are destroyed by the hemolymph phagocytes and that a capsule—an inflammatory membrane—forms round the pigment masses (remnants of phagocyte-digested bacteria). It is practically impossible to establish morphologically whether certain individual bacteria survive in the mass of pigment substance (remnants of bacteria), while retaining their properties. An experiment was carried out with inoculation of a guinea pig with an emulsion from bee moth containing pigment masses—remnants of destroyed tuberculosis bacteria. In such cases, the guinea pig developed tuberculosis and died, apparently, due to a certain number of live bacteria which might have remained in the bee moth and caused a fatal infection (according to K. Tumanov's written report).




F i g. 29. Diagram showing infection of man by spirochetes, the causative agents of cosmopolitan relapsing fever, from a specific vector—the human louse *Pediculus humanus*. Original drawing by E. N. Pavlovsky.

The arrow with cross indicates the route of spirochetes transmission after crushing a louse (grattage); the continuous arrow indicates infection of a louse drawing blood from a relapsing fever patient harbouring spirochetes; the dashed arrow shows a direct contaminative infection of the mucous membranes and conjunctiva of man from crushed lice or from newly-contaminated environmental objects (for example, a door handle).

It follows from the above that the transmission of a pathogen by the vector from the donor to the recipient is also a complicated process influenced by numerous internal and external factors. To estimate this influence it is necessary above all to determine *the species of vectors and causative agents of a particular disease* with regard to the species of donor and recipient. The research should, therefore, be carried out by induction, refraining from inadequately grounded, sometimes quite arbitrary analogies, but admitting certain working hypotheses advanced at one stage or another on the basis of the studies undertaken.

Flimsy hypotheses only interfere with an understanding of the details of the process by which a pathogenic agent is transmitted by its vector.

At a certain temperature, some vectors may attack and feed upon engorged individuals of their own species. Such "cannibalism" is observed among the vectors of trypanosomes causing Chagas' disease—bloodsucking triatomes (and in *Ornithodoros* and *Argas* ticks). Hungry nymphs of these semicoleopterous insects, when kept at a temperature of 37-38° C together with engorged nymphs of the same species attack the latter, puncture their inflated bodies and draw their contents, thereby receiving the pathogen harboured by their prey. For a disease-producing agent to be transmitted by

a vector to a recipient (including man), the vector should be *aggressive* with regard to the recipient, man in particular.

Some species of fleas do not feed on human blood in general, whereas other species, for example, the suslik flea of the Volga basin—*Ctenophthalmus breviatus*—as well as fleas of the species *Ct. agyrtes*, *Ct. segnis* and *Xenopsylla astia* reluctantly feed on human blood, while suslik fleas of the species *Ceratophyllus tesquorum* and *Neopsylla setosa* are very aggressive to man (I. G. Ioff et al.). This alone is enough to account for the variable role played by plague-infected fleas of different species in the transmission of this infection to man.

Also less aggressive to man is the tick *Haemaphysalis concinna*, the vector of the tick-borne encephalitis virus, compared to another vector, *Ixodes persulcatus*; in addition, the former attaches itself to the human skin slower and less firmly than the latter.

## FLEAS AS VECTORS OF PLAGUE BACILLI

Turning back to the mode of infection transmission, one should note its quite distinctive character in the case of fleas. Indeed, when biting a sick animal harbouring plague bacilli in its blood the flea receives them into its foregut and stomach, where they rapidly multiply and obstruct the foregut with their mass. Nevertheless, the flea still attempts to have another meal of blood, on another animal. A certain amount of it enters through the esophagus into the anterior portion of the obstructed foregut. Its passage into the stomach is blocked, and, like in vomiting, this blood turns back having captured a certain number of plague bacilli from their agglomeration. The blood containing bacilli flows back into the animal's body contaminating it with the infection.

Fleas avidly draw blood, which fills their alimentary canal and appears at the anus. If their prey is a plague-affected animal, plague bacilli may be discharged through their anus with infected blood. The latter quickly dries up, and this poses the question of whether and how long bacilli remain infective in dry flea feces especially as a flea can thus discharge up to 24,000 plague bacilli. It commonly takes in up to 60,000 microbes, and 300,000 at most. Most researchers consider that plague bacilli are not harmful to the flea itself. However, bacteria multiplying in the flea foregut and stomach may completely obstruct its alimentary canal which becomes impermeable to blood, as a result of which the flea may be starved to death.

D. A. Golov and I. G. Ioff (1928) observed the survival of plague bacilli in fleas up to 396 days, and suggested that such viability practically continues through their lifetime. In *Rhadinopsylla liventricosa* fleas plague microbes survived up to 420 days (Sharets et al., 1958).

But in many cases, however, there apparently occurs self-purification of fleas engorged with blood containing plague microbes. This process is induced by the influence of a bacteriophage which has entered the flea stomach. Causing lysis (dissolution) of plague bacilli, the bacteriophage eliminates them in 60 to 70 per cent of plague-infected fleas in one to three and a half months' time (Tiflov, 1944).

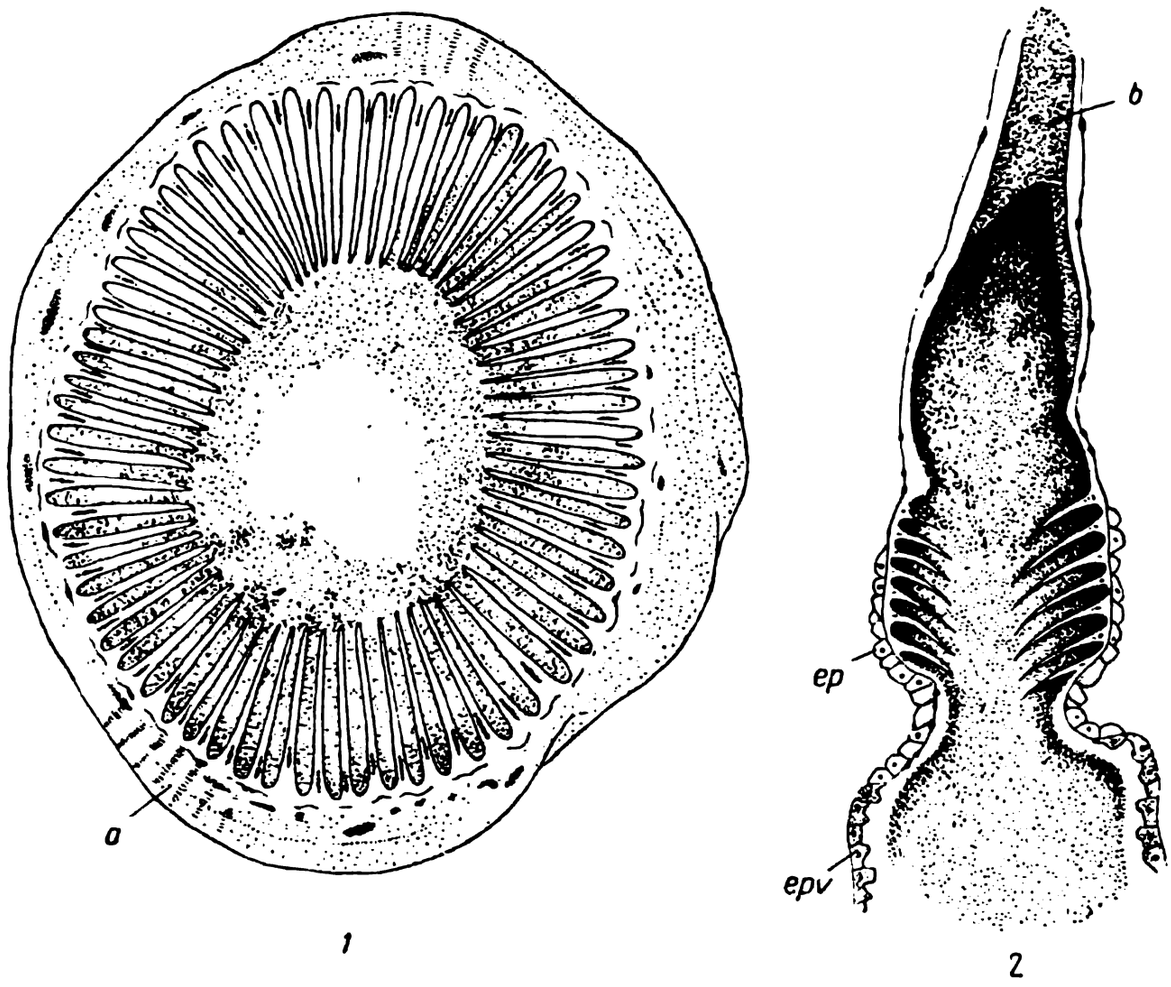
The duration of survival of plague bacilli in dry feces of fleas depends on the influence of light and temperature. In the dark and at room temperature, plague microbes can survive up to 18 months (Blanc et Baltazard, 1946), and under laboratory conditions in vacuum-sealed ampules up to 941 days (Blanc, 1948).

The inner surface of the flea foregut is covered with digitiform, pointed outgrowths, with a valve between the foregut and stomach. These structural features influence the formation of a plug by plague bacilli obstructing the foregut (Figs. 30, 31).

Male and female fleas have certain differences in their foregut structure. For example, in *Xenopsylla cheopis*, *X. astia* and *Ctenocephalides felis* fleas captured on rats in Bombay the females had a considerably larger foregut and almost twice as many digitiform outgrowths (projections) as the males. The number of such outgrowths in the flea foregut decreases with age. Owing to this, old fleas are capable of ingesting much more blood than young ones and in their foregut a much larger aggregation of plague bacilli is formed, let alone the fact that this aggregation in females is generally larger than in males. In the view of some authors, female fleas are more capable of transmitting plague bacilli than males. But whether this is related to the number of outgrowths in the flea foregut is uncertain.

The number of plague bacilli in infected fleas collected during an epizootic may reach several million. The alimentary canal of a flea obstructed by plague bacilli can be observed through a low-power microscope. The actual invasion of such fleas by plague bacilli was subsequently verified by the cultivation of the contents of their alimentary canals (Quan, Kartman, Prince a. Miles, 1960).

As far back as 1931, V. A. Bychkov and A. K. Borzenkov employed manual dissection of plague-infected fleas and proved the possibility of visual observation of the obstructed alimentary canal of fleas so as to determine their infection with plague bacilli. The material under examination were dissected stomachs from 100 fleas collected in burrows of the *Citellus musicus* suslik. The fleas had been captured in autumn and were kept in bags till mid-December, when the study was commenced. The stomachs of some fleas contained fresh blood while other stomachs were empty or contained gas bubbles, sometimes spherical gregarine cysts, and apparently fatty drops. The fleas were planted on plague-affected animals at one and the same temperature (14-15°C), yet not all of the fleas were willing to feed. For example, in December and January, only




F i g. 30. Cross-sections of the alimentary canal of a flea. According to Bacot and Martin (1914).

*1*—transverse cross-section of the foregut of an engorged flea harbouring plague bacilli: *a*—striated muscular membrane of the foregut; protruding inside are chitin-covered digitiform processes of the epithelial layer of the foregut (white) and between them and in the foregut lumen (dots) are plague bacilli; the initial stage of agglomeration. *2*—longitudinal section of the esophagus, the foregut and the fore part of the stomach in a blocked flea: the black dots show the agglomeration obstructing the foregut and preventing the entry of absorbed blood (*b*); (*ep*)—the epithelial wall of the foregut; (*epv*)—the epithelial lining of the stomach.

34.3 per cent of the test insects showed a desire for food, in February even less—30.5 per cent and in May the percentage of feeding fleas shot up to 97.7 per cent. The most reluctant to feed were the males—in general a half of all those taken for the experiment, whereas for the females the respective proportion was one third.

At the later stages of the life of plague bacilli in *Neopsylla setosa* (15 days after infection) the walls of the stomach and foregut were translucent in a falling light beam. The foregut harboured an opaque compact mass extending into the stomach cavity as a white mass with a yellowish-pink hue. In the stomachs of numerous dissected fleas, one could see the entire gamut of changing colours of the central bacterial mass—from dark-brown to white.

That these were really plague bacilli was proved by their staining for microscopy and by bacteriological inoculations.

Bychkov and Borzenkov (1931) presumed that the plague microbes introduced with blood into the flea stomach and multiplying within it decompose the hemoglobin, owing to which the stomach contents turn white. The noted changes of colour were found in 63 per cent of plague-infected fleas and may, therefore, aid in the diagnosis of spontaneous infection of fleas by plague bacilli.

The probability of fleas taking up infection from plague-affected susliks is related to the titre rate (number) of plague microbes in the blood of a diseased donor, i.e., to the degree of septicemia. For instance, 15 to 50 per cent of all experimental fleas become infected from susliks with moderate septicemia, as has been reported by D. A. Golov and I. G. Ioff.

The survival of virulent plague bacilli in the flea body depends on the temperature of the external environment. At 30-32°C plague bacilli disappeared from the bodies of engorged fleas soon after they had been fed, whereas in infected fleas kept at a temperature of 22-25°C plague bacilli survived as long as 3 weeks. At a still lower temperature of 7-8°C and with adequate humidity, plague microbes survived in starved rat fleas (*Ceratophyllus fasciatus* Bose) up to 47-50 days (Bacot a. Martin, 1914). Golov and Ioff (1926) managed to observe the survival of virulent plague microbes in live suslik fleas for over half-a-year (!).

The epizootiological importance of fleas as plague vectors, for example, suslik fleas depends on the degree of affinity of various flea species to the host—the occupant of a burrow in particular. Thus, the *Ceratophyllus tesquorum* lives in the hair of its host (suslik) approximately four times longer than the burrow fleas; therefore, fleas of the aforesaid species feed more frequently. In addition their migrating activity is around three times as great. Moreover, fleas of this species are in fairly large numbers found in burrows of the small suslik round the year. On account of these circumstances, *C. tesquorum* fleas are more active plague vectors than the other species, *Neopsylla setosa*, which is also parasitic on susliks.

This conclusion is also corroborated by direct evidence. According to observations in 1950, in the area of a suslik epizootic in Western Kazakhstan the prevalence rates for *C. tesquorum* were a good ten times those for *N. setosa* and the numbers of *C. tesquorum* fleas directly infected by plague microbes were five times those of *N. setosa* (Novokreshchenova, 1962).

The study of flea ecology becomes more and more profound, along with advances in their systematics, the necessity of which is increasingly evident from the available data on their biology and the variable degree of the relationships of fleas (elementary and contact) to a specific host. Contact relationship implies the length of time spent by fleas in the host's hair and in the burrow itself. More, as regards the associations of fleas with their locations it is no longer sufficient to simply specify that a particular burrow harbours a

particular number of fleas. The ratio is determined of the number of fleas in the first knee of the burrow (i.e., in its exit) to that in its deeper parts, and is used as the basis for judgement on the migration of fleas. In the colonies of gerbils in the Northern Kyzyl-Kum desert, of the total number of *Xenopsylla gerbilli caspica* collected in burrows and on their hosts only 3 per cent of all captured fleas were discovered in the first knees of burrows, whereas excavations of wider and deeper passages in the central parts of the colonies revealed the largest numbers of fleas. These parts of the colonies are also the abode of gerbils for the most part of the year; it is here they store their grass feed in autumn. In the gerbil nests themselves, however, the prevalence of *X. gerbilli caspica* was considerably smaller, constituting not more than 17.5-22 per cent of all fleas captured during the excavations of burrows (Novokreshchenova, 1962).

Man can also exert an indirect influence on the prevalence of fleas in some parts of their host's burrows. Thus, during agricultural rodent pest control in the steppes, poison baits are placed outside of the burrows instead of the more labour-consuming method of introducing a pesticide, e.g., chloropicrin, into each burrow by hand followed by their closure with earth. In the latter case, all inhabitants of the burrow are killed, whereas in the former case the only victim is the rodent eating the bait while the fleas remain utterly unaffected by it. When the burrow host has been killed the fleas deprived of their source of food begin to draw towards the burrow entrance and, possibly, find their way out to the earth surface.

Cases are known of people being infected with plague when staying the night in the steppe. The cause of it can be accounted for only by the bites of plague-affected fleas migrating from a burrow.

## PATHOGENIC AGENT VIRULENCE AND ITS VARIABILITY * AS EVIDENCED BY *BACILLI PESTIS*

The infective state of a pathogenic agent is known as its *virulence*, the degree of which (or infective capacity) is variable. A pathogenic agent may sometimes lose its virulence under the influence of certain factors though retaining its viability and its immunizing properties. This was observed in plague bacilli, when its *avirulent* (i.e., incapable of infection) culture had been isolated. Such avirulent cultures can be used for prophylactic inoculations (vaccination).

After 13 years' futile search for plague bacilli in the western part of a plague focus in the Borzin district of Chita Region five

* For data on the variability and mutations of bacteria see the corresponding chapters of the *Manual of Microbiology, Clinical Picture and Epidemiology of Infectious Diseases*, vol. 1 (Moscow, 1962, pp. 473-559—Kudlai and pp. 560-573—N. N. Zhukov-Verezhnikov and A. P. Pekhov).

strains of the *Bacillus pestis* were isolated in 1960: from the Daur hamster, *Frontopsylla luculenta* fleas sheltering in suslik burrows, the Daur suslik, adult Brandt's vole and its young. The isolated strains were distinguished by a decreased virulence to albino mice and absence of virulence to guinea pigs. These findings are indisputable evidence of a continued prevalence of plague in the natural surroundings of the Trans-Baikal focus, though no cases of plague have been registered among humans in this focus since 1937 (Larionova et al., 1961).

One of the forms of the variability of pathogenic microbes is their dissociation ("disconnection", "fragmentation"—in the sense of formation of different variants of the initial pathogenic strain). Thus, the dissociation of the *Bacillus pestis* leads to the formation of the S-variant and R-variant of this bacterium (Bezsonova and Lenskaya, 1929; Lenskaya, 1947). A. A. Bezsonova, G. N. Lenskaya, P. F. Molodtsova and O. N. Mosolova (1936) reported a case of genuine spontaneous mutations of five plague bacillus strains; all of the mutants proved to be close to the causative agent of pseudotuberculosis of rodents.

N. N. Zhukov-Verezhnikov and M. M. Khvorostukhina (Zhukov-Verezhnikov, 1936, 1940; Zhukov-Verezhnikov and Khvorostukhina, 1940) reported that an artificial mutation of the plague bacillus takes place under the influence of the homologous bacteriophage. During a study of these mutants for almost 10 years at the "Microbe" Institute it has been found that some of them increasingly deviate from the parent plague microbe strain.

Mutants and dissociants rarely occur in nature. "The cultures of plague microbe mutants arising at present are undoubtedly the result of species-forming variability in the direction of the pseudotuberculosis microbe of rodents" (Lenskaya, 1947, p. 76).

The five slightly virulent plague bacillus strains isolated in the Borzin District of Chita Region (Trans-Baikal area) were quite typical as far as the morphological signs of their growth on nutrient media, their sensitivity to the specific phage, and other characteristics were concerned. These strains, however, even in doses of 10,000-15,000 million microbial bodies failed to infect guinea pigs, just as a number of steppe rodents. The isolated strains proved to be of low infectivity to albino mice. Moreover, these strains were found to be capable of increasing the resistance of animals to subsequent infection with plague microbes commonly virulent to them. This is proof that a natural plague focus may be sustained in a torpid state as a result of the circulation of such attenuated plague microbe strains among wild rodent donors and recipients, and it is quite probable that, given appropriate conditions (which should be ascertained) such a torpid natural plague focus may turn into a hotbed of a plague epizootic.

## THE RATE OF PATHOGEN TRANSMISSION BY AN INFECTIVE VECTOR

In frequent cases, disease-producing agents may be repeatedly transmitted by one and the same vector, often throughout its lifetime (if a given insect vector draws infected blood more than once).

Things take quite a different turn during the transmission by lice of the agents of relapsing fever which are called spirochetes on account of their spiral shape. The spirochetes gain entrance to the louse body just as the *Rickettsia* organisms causing typhus—through the esophageal orifice. But the spirochetes have no exit from the louse body. They enter the louse body cavity which in none of its points opens outside, and for this reason is a kind of *a cul-de-sac* for relapsing fever spirochetes. But how can people be, nevertheless, infected with this disease by the agency of lice? When biting a human being the louse impregnates him with its salivary fluid which is a mixture of secretions from its minute salivary glands called bean-shaped or horseshoe-shaped for their characteristic form.

The salivary fluid (secreted by the bean-shaped glands in particular) not only irritates the skin but causes a certain degeneration of its malpighian strata under which a cornified membrane remains at the site of the bite. When scratching the itching places of the skin this membrane is easily scraped off. Simultaneously, a spirochetes-infected louse may get under the finger nails and be crushed or have its legs broken off, as a result of which its bodily contents (viscera, hemolymph, i.e., its "blood") are spread on the sore, the spirochetes invading the human body and producing disease.

Consequently, *it is only once that an infected louse can transmit relapsing fever spirochetes, since this involves its rupture by scratching (grattage) and death.*

It is evident from the above examples that the mode of disease transmission by vectors is variable. It should be known exactly so that preventive measures can be taken in good time to safeguard man from transmissible diseases. Yet the mode of transmission is only the last stage in the intricate route by which the pathogen enters the vector body, where it develops and multiplies and gains access to the exit.

These facts should be clarified in adequate detail, since they determine the very process of disease transmission by a vector to man.

## THE DISTRIBUTION OF VIRUS IN THE TICK VECTOR BODY AND THE VIRUS INFLUENCE ON THE RECIPIENT (DISEASE, IMMUNITY, DURATION OF CARRIER STATE)

Hungry females of vector ticks (*Ixodes persulcatus*) were easily infected when fed on albino mice containing tick-borne encephalitis virus in their blood (virusemia). By the 6th day after the commence-

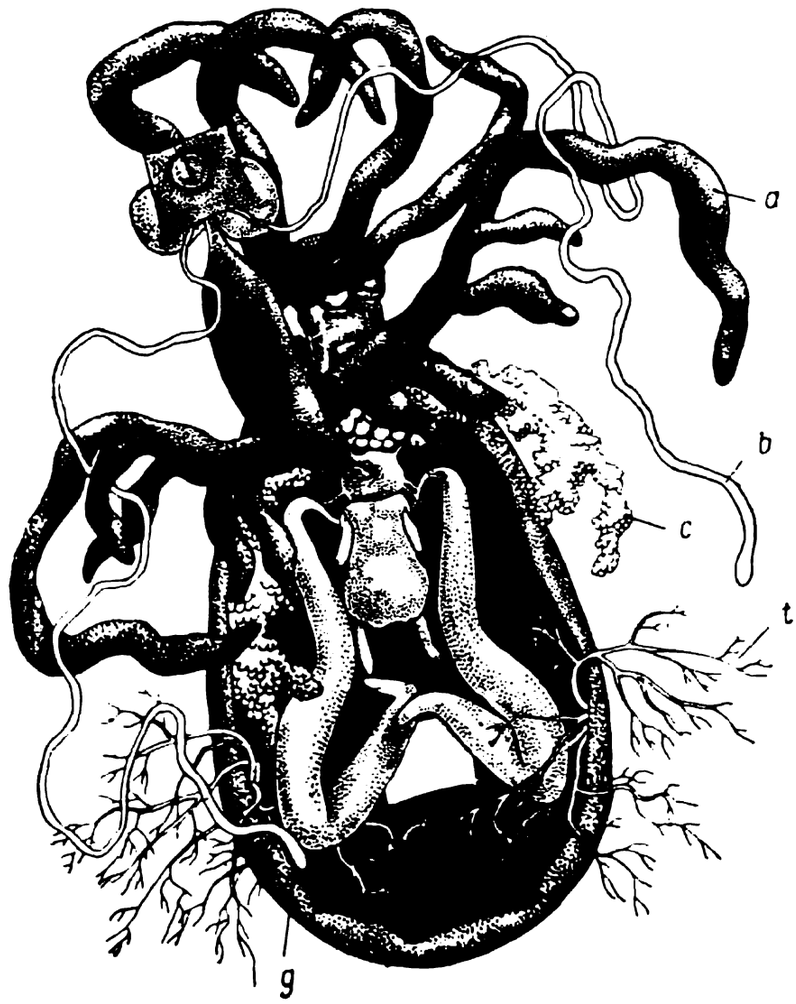



Fig. 32. Dissected *Haemophysalis punctata*: intestinal loops (*a*) pulled forward. According to E. N. Pavlovsky.

*b*—malpighian vessels; *c*—salivary glands; *t*—tracheae; *g*—genital glands.

ment of the feeding the tick-borne encephalitis virus passed from the stomach of the engorged female tick into its body cavity and was found to be active in all of its organs. This was established in experiments with isolation of different organs when dissecting an engorged tick (Fig. 32) and preparing an emulsion from them for its subsequent injection into the brain of an albino mouse. An emulsion prepared from *any organ* of an infected tick caused fatal encephalitis in mice.

The virus contained in the ingested blood undergoing digestion retains its infective power within the intestine for 25 days of an experiment, even if the emulsion from the intestine has been taken for the experiment in a weak dilution in an indifferent liquid.

Having entered the genital system of the female (ovary and oviducts), the virus at first decreases in amount but by the 25th day of the experiment is restored almost in full. The presence of the virus in the tick's genital system does not interfere with the maturation and fertilization of the ovi, and the female lays eggs already

harbouring encephalitis virus. Consequently, the oviposition is accompanied by the elimination of virus from the female body.

The usual embryonal development of the tick occurs at an appropriate temperature in the external environment inside of tick eggs impregnated with the virus at the time of their presence and development in the maternal body. Once the embryo has attained maturity, it emerges from the egg as a larva and some time later, when its chitin cover and mouth parts have grown strong enough, attaches itself to the host. By this time, the encephalitis virus has accumulated in the larva's salivary glands and is transmitted with the salivary fluid to the host on which the larva feeds and which it infects with encephalitis virus. This is known as the so-called *transovarial transmission of virus* from the mother tick to larvae representing its first daughter generation. The transmission of virus to larvae is called transovarial because the virus from the body cavity of the infected mother tick penetrates through the membrane of the ovary (ovarium) into the eggs developing therein. This is, in effect, the earliest possible infection of the future larvae when they are still present as an egg stage inside the maternal body.

The larvae infected from their mothers feed on their hosts and in time cast their chitin coat, i.e., turn into nymphs. The larva has six legs, and the nymph has eight: having gained strength after a molt the nymph also bites the host and impregnates it with the virus (transphasic transmission).

An engorged nymph leaves the host and, given favourable conditions of the external environment (temperature, humidity, etc.), molts into a male or female imago. These in their turn attack the host, whose blood, in particular, is needed by the female for its eggs to mature and be subsequently deposited. Simultaneously, the females of the daughter generation transmit the virus to their host; in other words, the transovarial transmission of virus is replaced by transphasic transmission, and the former, as has been shown by M. P. Chumakov's experiments, extends to the second generation of the infected parent female tick. These are experimental data, and it is possible that in nature transovarial virus transmission extends even farther, to the subsequent tick generations (like symbionts among many insects): long follow-up studies are required to determine the precise number of such generations.

Experiments have proved that not all of the tick larvae of the daughter generation transmit the pathogen (for example, of tick-borne relapsing fever) to their hosts, but only a certain proportion of them. During the subsequent transphasic transmission, the proportion of ticks transmitting the tick-borne relapsing fever increases (Pavlovsky and Skrynnik, 1952).

It has been pointed out above that the virus seems to permeate all the organs of an infected tick. It penetrates even its salivary glands which are much smaller than the intestine. The virus invades also

its nerve ganglion formed by coalescence of the rudiments of several pairs of nerve ganglia in the abdominal nerve chain and the parapharyngeal nerve ring. An idea of the size of such a compact nerve system in the tick can be gained from the fact that the entire mass of cerebral ganglia from five ticks is less than the size of one salivary gland of a non-fed female tick (these glands are two, and they tend to increase in size while the tick is feeding). Such minute organs were used to prepare an emulsion, which was injected into the brain of albino mice. The mice developed encephalitis and died. This was evidence in favour of encephalitis virus being apparently present and accumulating in the organs from which the emulsions were prepared.

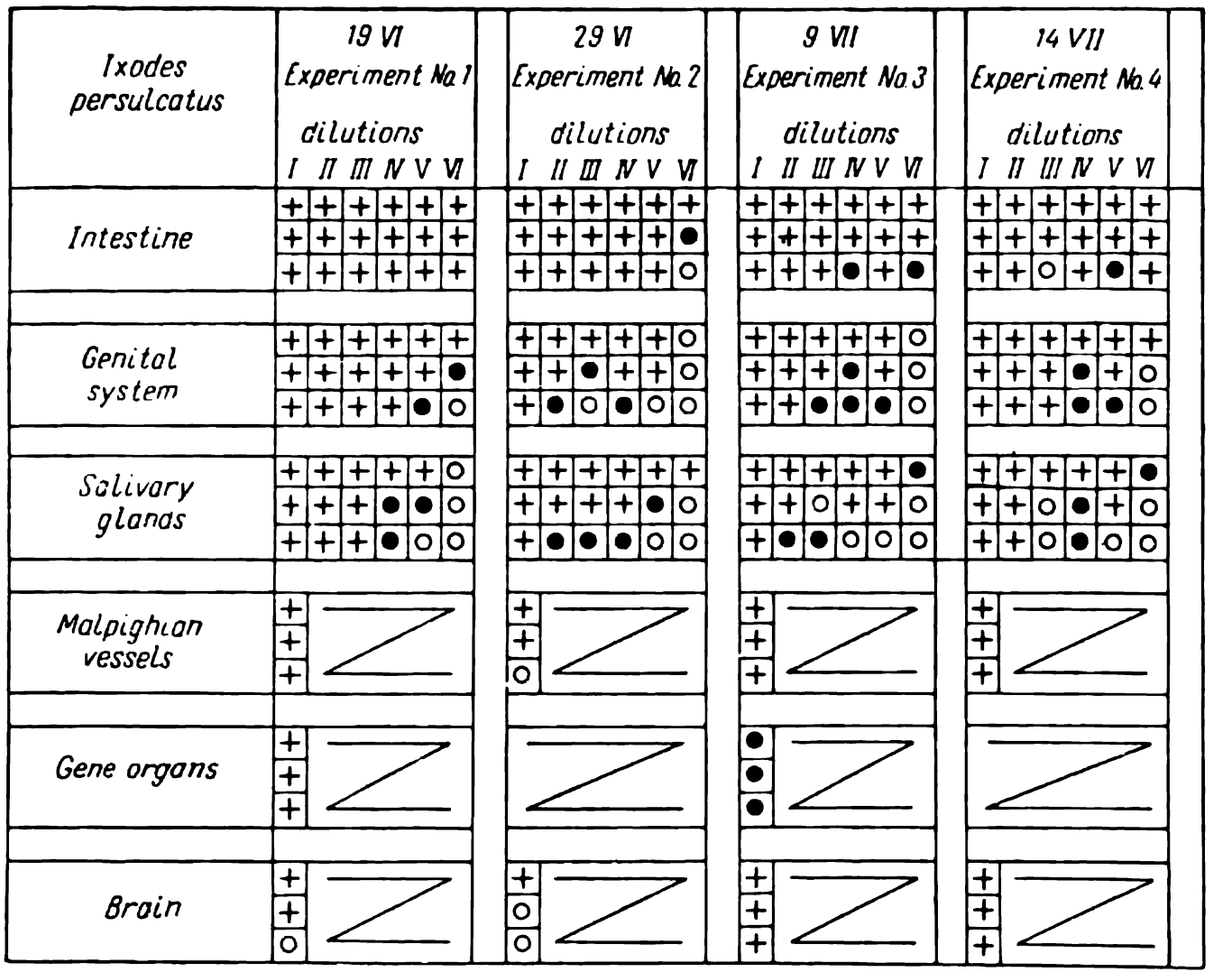
Considering the fact that the size of the salivary glands is very small and that of the nerve ganglion simply negligible as compared to the ovary and oviduct and that the injection of emulsions prepared from these minute organs may cause total encephalitis in mice, it is perfectly logical to draw the conclusion that the virus concentrates in the salivary glands and in the coalesced nerve ganglion or acquires a higher toxicity within them. The latter inference can be made from the fact that even the fifth and sixth successive dilution of the emulsion from these organs in certain experiments proved pernicious to albino mice.

At the same time, all series of experiments by E. N. Pavlovsky and V. D. Solovyov with injection of emulsions prepared from infected tick organs failed to cause a disease in a certain number of mice, while most of them died, exhibiting a typical picture of encephalitis (Fig. 33).

The surviving mice were subsequently infected for the purpose of verification with ten minimum lethal doses of encephalitis virus injected hypodermically. The mice remained healthy, which was evidence of their having acquired insusceptibility (immunity) to encephalitis virus.

The data of these experiments should, naturally, be compared with the results of examination of population groups exposed to tick-borne encephalitis hazards in their places of residence or employment.

Virologists (Levkovich et al.) have repeatedly undertaken examinations of such contingents as lumbermen and their families, wood-workers, forestry workers so as to ascertain whether their blood contains antibodies to tick-borne encephalitis virus. At the same time, all those examined were questioned as to when they had been ill with tick-borne encephalitis, if at all. It was found that the blood serum of persons who had obviously never suffered from this disease contained antibodies to tick-borne encephalitis virus. One may ask, what does this mean? Apparently, such people had been attacked by viruliferous ticks in natural surroundings. But the attacking ticks were either few in number or the virus injected with their salivary



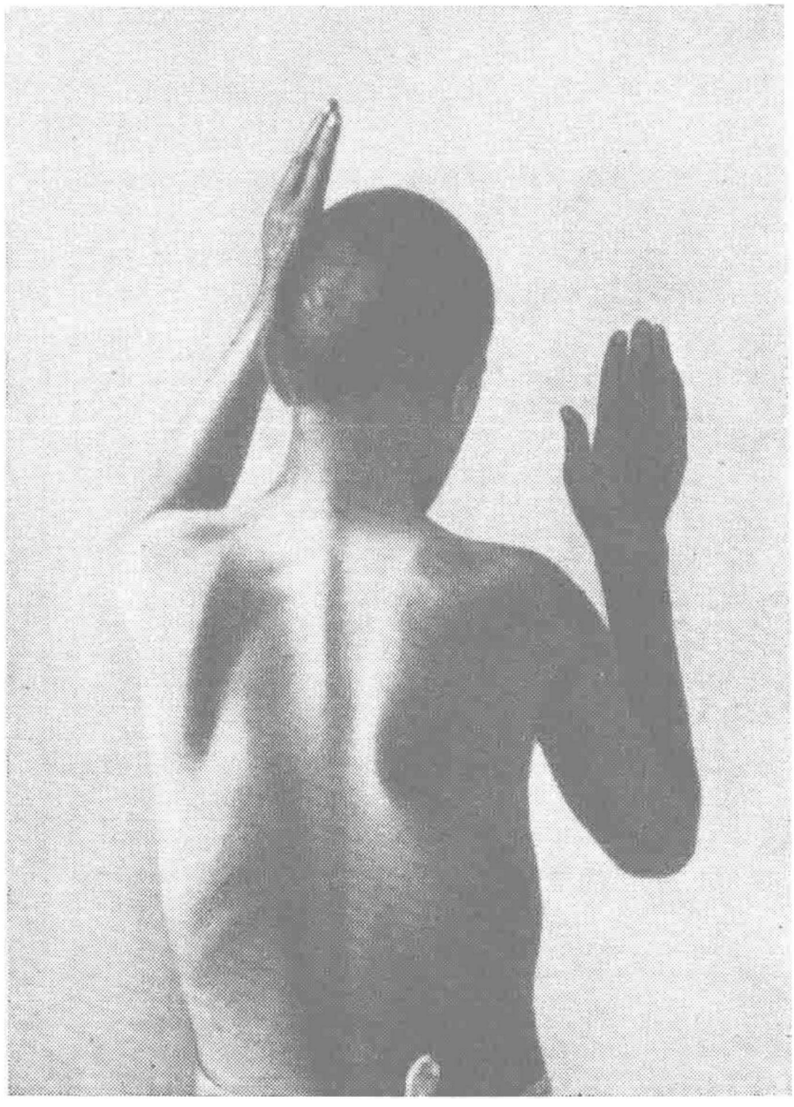

F i g. 33. Circulation of tick-borne encephalitis virus in the body of an infected *Ixodes persulcatus* female tick, determined by the method of emulsifying tick organs isolated manually and by hypodermic injection of the emulsions to albino mice. According to E. N. Pavlovsky and V. D. Solovyov, 1940.

Each square indicates an experimental mouse. Crosses indicate death of encephalitis; black circles indicate mice which did not become ill but acquired immunity to 10 DLM; pale circles indicate mice which did not contract encephalitis but died from other causes.

fluid was for some reason so attenuated as to be unable to cause a disease in humans, but nevertheless antibodies to encephalitis virus formed in the latter's blood.

Virologists have also established that the blood serum of persons having sustained tick-borne encephalitis, even years ago, contains substances which neutralize an active virus of this disease; in other words, people recovered from tick-borne encephalitis acquire immunity to its recurrence, which lasts for years, if not for life. This makes it possible to make a retrospective diagnosis of tick-borne encephalitis sustained by a given subject in the past.

Depending on the specific conditions of a locality, time, and situation, the tick-borne encephalitis virus may apparently produce the following three different effects in human beings bitten by viruliferous ticks of variable species and in different numbers: in some persons it causes a fatal disease, in others a disease with residual paral-



F i g. 34. Residual paralysis following recovery from tick-borne encephalitis. Paralysis of the shoulder muscles. The patient is unable to raise his right arm due to paralysis of the serratus anterior muscle.

ysis of various muscle groups upon recovery (Fig. 34) or with other, less severe manifestations, still in others it causes no disease at all but *vaccinates* them, i.e., contributes to the formation of antibodies to the virus and immunity to its infective doses. *Consequently, viruliferous ticks may either produce in human beings tick-borne encephalitis of variable severity and outcome or inoculate them with a live vaccine, as it were, conferring immunity from encephalitis.*

Unfortunately, this process does not lend itself to artificial control with a view to tick-borne encephalitis prevention. But it is possible to try and prepare a vaccine from viruliferous tick organs and test it on animals so as to ascertain its immunizing properties and, should the effect be positive, to use such a vaccine for intradermic inoculation (like smallpox detritus) to people and ward off this disease entailing dangerous sequels.

The causes producing such drastic changes in the virus properties are apparently dissimilar for different viruses, yet at least one

of such causes has been determined with regard to the virus of yellow fever, a severe tropical disease. It has been stated above that the keeping of mosquito vectors infected with yellow fever virus at decreasing temperatures tends to prolong the period elapsing before they become infective to animals. Such experiments by Hindle and Davis have already been mentioned (see p. 40).

Schuffner and his collaborators, however, have proved that at a temperature of 16°C the virus, far from being capable of causing a lethal case of yellow fever, produces immunity to this disease in test animals.

The existence of a virus in laboratory conditions can be sustained by the transfer of it from one susceptible animal to another. This is known as passage. A multiple passage of a neurotropic yellow fever virus through albino mice finally renders its transmission to mosquito vectors impossible. Thus, at the 170th passage it is no longer possible to implant the virus in *Aëdes* mosquitoes (chief vectors of this disease) by feeding them on albino mice infected by means of passages (Roubaud et Stefanopoulo, 1933).

The lymphocytic choriomeningitis virus not only survives but multiplies within an animal body whatever the route of infection may be, without any noticeable clinical manifestations of the disease (Shur, 1954).

In 1938 Traub managed to observe in experimental conditions the lymphocytic choriomeningitis carrier state in albino mice lasting up to 250 days, which was contingent on the mode of their infection. The virus was detected in the visceral organs, in the nasopharyngeal mucus and in the urine (cited from Kislyakova, Levi, 1954). The virus was also eliminated with feces. The virus carrier state in naturally infected mice apparently lasts for life without exhibiting any clinical disease symptoms. Experiments with infection of mice with lymphocytic choriomeningitis by planting the virus on irritated skin as well as by the oral route proved futile. A prolonged association of infected and non-infected mice failed to communicate infection to the latter (Kislyakova, Levi, 1954).

Traub observed a four years' lymphocytic choriomeningitis virus carrier state in an albino mice colony. The virus was chiefly transmitted from infected female mice to their offspring by the intrauterine route.

The duration of the presence of the disease-producing virus in the vector body and, consequently, the possibility of the latter transmitting it to the recipient are determined, apart from the vector lifetime, by the conditions of vector hibernation as well as by the transphasic and especially transovarial transmission of the infective agent, which may extend to several generations of the vector (tick-borne relapsing fever spirochetes and the tick *Ornithodoros moubata*).

## PRESERVATION OF VIRUSES IN THE LABORATORY AND TERMS OF SURVIVAL OF THE CAUSATIVE AGENTS OF DISEASES WITH NATURAL FOCI IN THE EXTERNAL ENVIRONMENT

Viruses are characteristically unable to exist outside of living cells susceptible to them. Therefore, they cannot be cultivated like bacteria which are inoculated into nutrient media and kept at a specified temperature, then transplanted, in a few days time, onto a fresh nutrient medium, and so on, even for a prolonged period.

But under special laboratory conditions, viruses can be preserved outside of a living organism, in particular during their desiccation at a low temperature (the so-called lyophilization), for example at —76°C and in a high-degree vacuum. This method of virus preservation is used on a wide scale.

The terms of survival of an infective agent discharged from the vector body into the external environment vary in the large with the type of infective agent and the type of vector, as well as the type of animal donor and the factors of the external environment (season of the year, location of the eliminated infective agent, weather conditions, etc).

How long can, say, rickettsiae—the cause of spotted fever—survive in wild and laboratory animals? This question concerns, in effect, the duration of inapparent or latent infections. It is believed that in wild rats the agent of rat-borne typhus survives for an indefinite time. According to Fox (1948), *Rickettsia orientalis* survives in the mouse body for 610 days.

In F. I. Krasnik's experiments (1961) on 3-4 weeks old cotton rats infected intraperitoneally with egg culture rickettsiae this typhus agent survived within their bodies for as long as 126 days upon infection, but it could be isolated only from those animals whose blood serum contained complement-fixing antibodies in adequate titres.

Starzhik observed almost one-year-long survival of typhus rickettsiae retaining their virulence in dry feces of infected lice. Blanc and Baltazard showed in many experiments that in dry feces of fleas rat-borne typhus rickettsiae retain their virulence for as long as four years and a half; an idea of their virulence can be gained from the fact that one hundredth of a milligram of dry feces from an infected flea is enough to infect a recipient.

Dry feces of rickettsiae-infected lice and fleas turn into dust and become air-borne. They may be inhaled by man and infect him with a corresponding form of typhus. Moreover, air-borne feces may settle on the mucous membranes, which in the view of Blanc and Baltazard is the main route of rat-borne typhus transmission among rats.

A laboratory worker may also contract typhus by the respiratory route when studying infected lice and inhaling dust from their dry feces.

The clothes of typhus patients extensively infested by lice become contaminated with their feces which dry up quickly and, when such clothes are sorted out or worn, turn into dust likely to be inhaled by man and cause infection.

Another factor contributing to the spread of infection is the use by healthy persons of objects left over from patients killed by diseases whose causative agents can for a certain time survive in the external environment (for example, plague, louse-borne typhus, etc.).

The presence of *Coxiellae*—the causative agent of rickettsiosis, which is known as Q fever—in experimentally infected *Ornithodoros papillipes* ticks during 18 months failed to produce a substantial influence on their virulence to guinea pigs. In general, however, the term of their survival in vectors uncommon to them, for example, in *O. papillipes* ticks kept at a temperature of 26°-27°C continued, in A. B. Daiter's and N. I. Amosenkova's experiments (1961), up to 816 days, the transmission of *Coxiellae* occurring in the course of the entire metamorphosis of these ticks or by the transovarial route. During 703 days' starving of experimentally infected ticks *Coxiellae* retained their virulence. They were eliminated with feces.

The agent of varioliform rickettsiosis was isolated by Levi, Kiselev, Chuyeva and Kislyakova (1954) from house mice which harbour corresponding rickettsiae; their vector is apparently the gamasid tick *Allodermanyssus sanguineus* from which it was possible to recover rickettsiae identical to those isolated from rodents.

According to data furnished by R. I. Kiselev (1954), this disease prevails in the spring and summer, and is endemic for the town, in which it may be confined to certain streets, houses and apartments. People become infected in rodent-infested places where they are liable to be attacked by infected gamasid ticks parasitic on rodents.

Now, let us discuss pathogenic bacteria.

In Novosibirsk Region, listerellosis of sheep prevails in winter. The disease was not encountered in summer, when sheep were kept on pastures. Listerellosis is a comparatively new disease with natural foci. Between 1950 and 1955, pure *Listerella* (*Listerella monocytogenus*) cultures were obtained by means of inoculating emulsions prepared from the viscera of sheep, geese, rabbits, calves, pigs, cats, dogs, and aborted bovine fetuses.

Stock farmers may contract infection from sick cattle and poultry (from their dead bodies and from clinically healthy animals upon abortion; Kornilova, 1956).

N. G. Olsufyev (1954) isolated *Listerella* organisms from many species of rodents, insectivores, and certain species of *Ixodes* ticks captured on neat cattle, thereby proving the existence of natural foci of this farm animal disease, which can be sustained in anthropurgic conditions by house rodents.

A characteristic feature of the sporogenous anaerobe *Bacillus tetani*, the causative organism of such a dangerous disease as tetanus, is the long survival of its spores in the external environment, i.e., in the soil which they enter with feces discharged by man and domestic animals. A saprophyte, the *B. tetani* normally inhabits the intestine of man and animals, and in this state is harmless to them. As a sporogenous anaerobe this microbe, its spores in particular, is resistant to the action of sterilizing factors. Though it is perfectly innocuous as an inhabitant of the intestine, the *B. tetani* turns into a formidable foe to man, once it has entered a wound contaminated with earth containing this microbe. Here the word "wound" has a wide implication, ranging from war wounds to suppurations, punctures, wedged-in splinters, scratches (when walking barefoot), i.e., to such negligible injuries which the sufferer often takes no care of. The infection may also be introduced by an injuring object contaminated by *B. tetani*.

In this connection, it is important to study the degree of contamination of soils varying in structure, composition and humidity. Investigation of numerous soil samples for the presence of *B. tetani* showed that the contamination rates (within the limits of investigation) for sandy soils were comparatively low (4 per cent), whereas wet garden soil and dunged soil, as well as hygroscopic soils with a considerable content of nutrient substances (black earth, loam) are much more often found to contain tetanus bacilli (up to 74-87 per cent) as compared with the other numerous soil samples under examination (Sakhnovskaya, 1959). The rates of household contamination of soil with feces may vary with different localities.

Tetanus is a characteristic soil-borne infection prone to a seasonal prevalence.

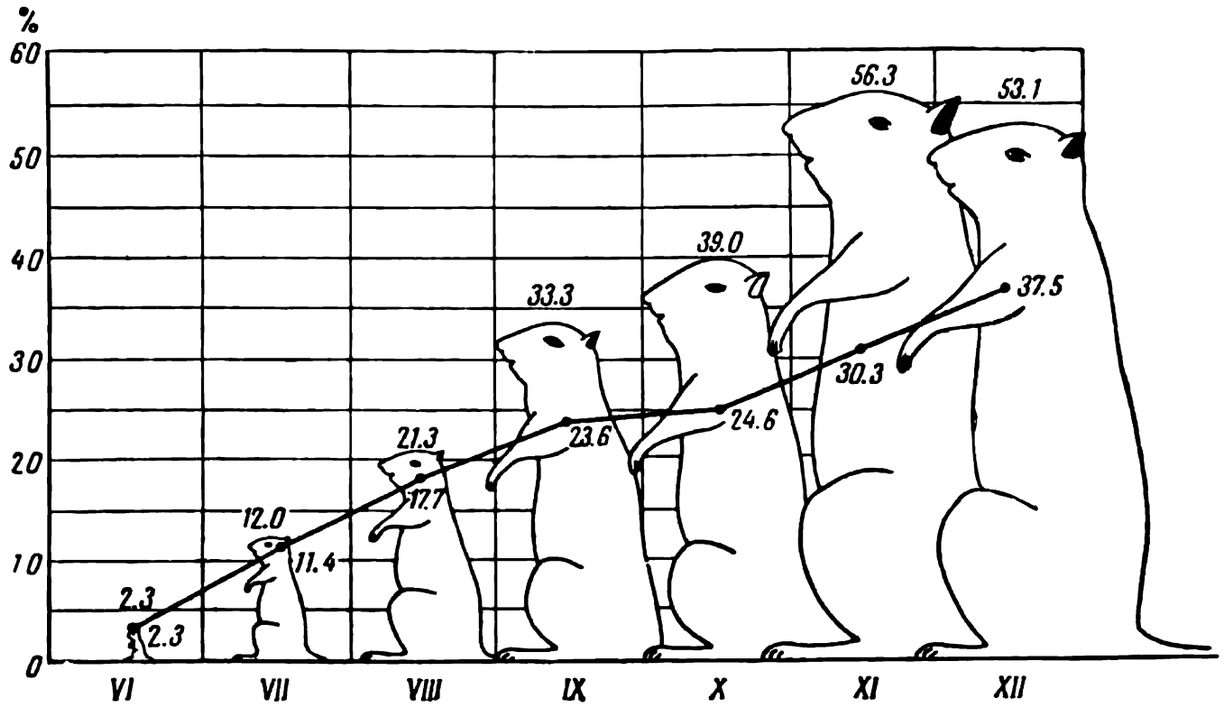
In peacetime, the tetanus rate is at its height from April through October (in the south), i.e., when work is in full swing on farms and in vegetable gardens. During this work, infection with tetanus most commonly occurs through wounds of the soiled feet; therefore, it is usually encountered in crop-farmers, rural residents, and their children.

Tetanus is a typical disease originating from the external environment as represented by the infected soil; therefore, detailed studies are required of various types of soil as well as of its household pollution and the contact of man with the soil.

But even for those disease-producing agents which are eliminated from the patient's body into the external environment—an atypical medium for survival—detailed studies are required of the duration of their survival in the soil in a virulent state, even if cases of infection with a corresponding microbe are rare. Even in such rare cases a detailed ascertaining of their causes requires information about the specific conditions which have contributed to the transmission of infection and subsequent disease.

## THE SEASONAL CHARACTER OF DETECTION (ISOLATION) OF PATHOGENIC AGENTS IN THEIR NATURAL FOCI

The rates of the recovery of pathogenic strains responsible for certain diseases with natural foci so as to ascertain the natural infectivity of donors captured in natural foci or during a search for the latter may also show seasonal variations. Thus, in spring and summer, *Bacilli pestis* could be regularly isolated from little




F i g. 35. Monthly incidence of cutaneous leishmaniasis among large gerbils in 1938 in the town of Imam-Baba in Turkmenia. According to N. I. Latyshev and A. I. Kryukova (1941).

marmots and their fleas (focus in the north-western Caspian littoral). In certain cases, *Bacilli pestis* were isolated from fleas in autumn and winter.

*Bacilli pestis* cultures could be isolated in quantity from house mice in the autumn and winter of 1932-1934, which was a period of mass reproduction of these rodents. In other years, however, *Bacilli pestis* could be obtained from them only occasionally [Mironov, Tinker, Shiranovich, and Shishkin, 1959 (1960)]; the rate of leishmania infection in the large gerbil also showed monthly variations (Latyshev and Kryukova, 1941) (Fig. 35).

## THE AGENTS OF ANTHRAX AND OTHER DISEASES IN THE EXTERNAL ENVIRONMENT (WATER, SOIL, HOUSEHOLD UTENSILS)

Highly important on account of their long survival in nature are the sporogenous bacteria, in particular the *Bacillus anthracis*, the causative organism of anthrax.

Fig. 36. Anthrax bacteria in the blood (bacteriemia). According to N. G. Olsufyev.

Anthrax bacteria (Fig. 36) are transmitted mechanically by large bloodsucking horse flies, but this disease may also be contracted when wearing clothes made from the wool or dressed skins of animals killed by anthrax, and when using household utensils, inasmuch as the spores of these bacteria are very hardy and retain their viability for a long time (see also p.18).

The transmission of anthrax agents by horse flies of the genus *Tabanus* is evidence of the great influence exerted by the external environment on this process, either facilitating or hampering it.

In the northern regions of the U.S.S.R., various water reservoirs dry up during a hot summer or leave only small pools to which anthrax bacilli spores may gain access by various routes. Swarms of horse flies drinking such water may acquire infection from it,

or they may infect it with anthrax bacilli themselves, thereby contributing to the spread of anthrax in nature. To horse flies themselves, the anthrax bacilli are perfectly harmless.

Considering the question of the presence of highly virulent bacteria in the external environment, one should recall the experiments by E. I. Kletz and Z. I. Shchekunova (1961) who found out that the plague vaccine strain 17 survived in tap water up to 1,450 days, whereas in sterile soil, bouillon, and physiological solution it remained viable up to 1,700 days (these figures indicate the term of observation). In non-sterile river water virulent *Bacillus pestis* strains retain viability up to 114 days, while their initial virulence lasts up to 93 days (Garmazova, Konstantinova, et al., 1961).

The tularemia microbe (*Bacterium tularense*) survives in water up to 3 weeks at a temperature of 20°-21°C in the presence of a decaying body of a water rat killed by tularemia.

## EXPERIMENTAL STUDY OF TRANSOVARIAL TRANSMISSION OF *COXIELLA BURNETI* IN HENS

The transovarial transmission of a disease-producing agent occurs in vertebrate animals as well. This has been proved experimentally with regard to the agent of Q fever (rickettsiosis due to *Coxiella burneti*) in the process of its circulation in the hen body whose infection by these rickettsiae fails to cause any clinical manifestations (Soběslavský, Syrůček, 1959). Soběslavský and Syrůček infected hens by mouth, and 26 to 64 days later discovered *Coxiella* organisms in eggs laid by the infected birds. Rickettsiae could be isolated by cultivation from the yolk-sac of a developing chick embryo. Even more significant was the intensive elimination of *Coxiella* organisms by chicks hatched from eggs laid by infected hens. When chicks of the first generation had attained reproductive age they also laid eggs which were found to contain *Coxiellae* in their yolk-sacs. The ovaries of a hen of the second generation from an infected parent were also found to harbour *Coxiellae* when it was eight months old, which is evidence of a long-term and continuous existence of *Coxiellae* in the infected parent hen and in its first and second generations.

# CHAPTER III

# VECTORS OF AGENTS PRODUCING DISEASES WITH NATURAL FOCI

## FORMS OF TRANSMISSION OF DISEASE-PRODUCING AGENTS BY VECTORS AND FACTORS OF THE EXTERNAL ENVIRONMENT

The forms of transmission of disease-producing agents by vectors are varied, and can be schematically presented as follows:

"Specific" transmission of the pathogen connected with its sexual or asexual reproduction within the vector body

↙ Transmission of the agent in an infective state to man and animals by puncturing their bodies with mouth parts, i. e., by *inoculation of pathogen* contained in *the salivary fluid*; inoculative transmission.

↘ Transmission of the agent to man and animals by *contamination* of their skin with infective vector feces, i.e., *contaminative* or *grattage* transmission.

↘ ↙ Combinative transmission of the agent — *by contamination of the skin and entry of infection through punctures made by vectors biting man or animals.*

It has been pointed out above that the reproduction of the disease-producing agent within the vector body and the mode of contagion are markedly influenced by factors of the external environment, above all by the temperature which either *favours* the entire complex of the processes of pathogen transmission by vectors (in particular, its propagation, gaining access to the exit from the vector, and in this connection the latter's behaviour under variable weather conditions) or, on the contrary, *prevents* at a given time the possibility of a pathogenic agent being transmitted by a hungry vector, even if on account of the latter's temporary abstinence from food.

To put it differently, factors of the external environment in a natural disease focus either *facilitate* the circulation of a pathogenic agent in this focus, or *do not hamper* it, or else *arrest* this process at a certain stage. To ascertain the relationships of the process of

pathogenic agent circulation in a natural disease focus, including the mode of infection transmission by vector to recipient is indispensable for finding out the causes of virulence of a natural focus, or of spontaneous reduction of its infective power, as well as for eliminating this focus by appropriate measures.

It is clear in the light of these data that the duration (stability) of the natural focus of a transmissible disease is determined by the character of its specific biotope and the latter's biocoenosis of the following composition: (1) animal donors; (2) vectors; (3) animal recipients; (4) the pathogenic agent itself in an infective state with (5) the influence of factors of the external environment contributing to an unhindered transmission of infection from one organism to another (circulation of pathogenic agent). Figuratively speaking, *the existence of the natural focus of a transmissible disease depends on a continuous interaction of the quintet (five) of its prerequisites associated with a specific geographical landscape.*

The disease-producing agent may be present in the external environment or only in the animal body. Many specific obligate transmissible diseases are characterized by the absence of their causative organisms in the external environment proper (at the current stage of evolution), the organisms being harboured exclusively by animal donors, vectors or animal recipients. A classical example of this is the malarial plasmodium, a primitive single-celled protozoon which never occurs in the external environment.

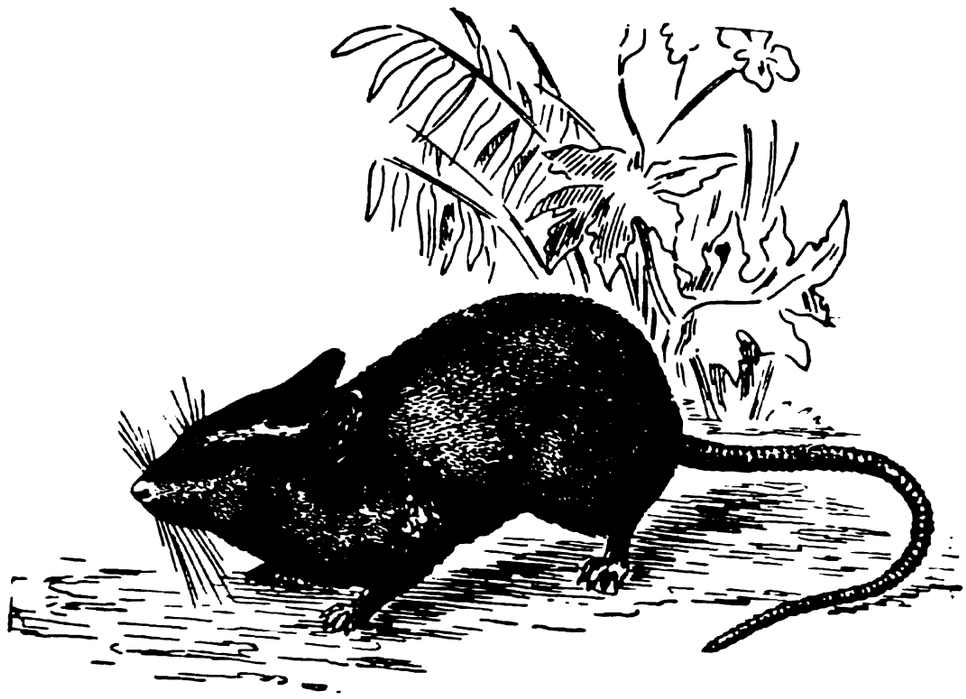
## THE SIGNIFICANCE OF VECTOR AND DONOR RESERVOIRS OF INFECTIONS WITH NATURAL FOCI

The donor is a term applied to any living body which has received, by any route whatsoever, a disease-producing agent, and contains it in the blood (the state of virusemia, bacteremia, parasitemia) or within some other organs from where it may be taken up by a vector or directly by a recipient.

The question is whether the donor and vector play equal roles as reservoirs of an infection. The answer is negative, since their roles vary with the degree of their susceptibility to infection.

Very prone to a specific infection are those species of animals which can be infected by *only one microbial cell* from a highly virulent culture. The implanted microbe multiplies in the body of such an animal, the infection becomes generalized and fatal. This is the case with field voles, shrews, and mice, except field mice (Fig. 37), affected with tularemia.

For infecting other animals, such as susliks, field mice, beavers, etc., the minimum lethal dose of a highly virulent *Bacterium tularense* culture should contain tens and even hundreds of thousands of microbes; with a smaller dose the disease takes a chronic course or



F i g. 37. The field mouse.

gives no symptoms in certain cases, and upon clinical recovery such animals remain bacilli carriers. There are animal species completely immune to tularemia in nature, for example, carnivores.

It is important to clarify the significance of animal donors and recipients in sustaining the circulation of *Bacterium tularense*, i.e., for the existence of a specific natural focus of tularemia.

The true reservoirs of *Bacterium tularense* are, as has been proved by N. G. Olsufyev, *Ixodes* (pasture) ticks. For them to be infected in nature it is necessary to have such species of animal donors as would be liable to a generalized infection, when their blood contains enough *Bacteria tularense* to infect a vector. For the subsequent circulation of the microbe, the biocoenosis of a particular pasture should include animal recipients highly susceptible to tularemia. The animals of the first of the above-mentioned group do possess such characteristics. Animals with chronic or asymptomatic tularemia, however, can hardly transmit *Bacteria tularense* to tick vectors in all cases. When a tick feeds on the tularemia-infected blood of a carnivore, the microbe finds itself as though in cul-de-sac, because fresh groups of biting ticks will be unable to take a sufficient number of microbes from the blood of such beasts practically immune to tularemia and pass into the infective stage themselves, as a result of which the circulation of microbes along this line comes to an end.

The sequels of infecting *Bacterium tularense* vectors, *Ixodes* ticks in particular, are determined by the peculiarities of the course of tularemia in animal donors, in other words, they depend on the character or gravity of the pathological condition of the infection

donor belonging to a group of animal species variably susceptible to tularemia. V. G. Petrov and T. N. Dunayeva (1955) ascertained the relationships of the tularemia infection rate in larvae of the tick *Dermacentor marginatus* being fed on animal donors grouped by N. G. Olsufyev and T. N. Dunayeva (1960; Dunayeva, 1954), in the order of species, into (1) animals highly susceptible to tularemia, in whose bodies *Bacteria tularense* multiply intensively, and (2) animals slightly susceptible to this microbe which propagates inside their bodies on a limited scale. The ticks were infected by feeding them on tularemia-affected animals—common voles, ratlike hamsters (1st group), field mice, albino rats, susliks and common hedgehogs (2nd group). The authors' experiments carried out over many years showed that tick larvae fed on infected donors highly susceptible to tularemia (1st group) usually readily took the infection and transmitted it to the subsequent stages of metamorphosis, i.e., after corresponding molts with transformation into nymphs and the latter's into females and males (the so-called transphasic transmission of infection).

The infection rate in larvae depended on the time of entry of tularemia microbes into the blood of the test animal—host of tick larvae—and on the subsequent aggravation of bacteremia to a fatal degree.

Tick larvae removed or fallen off within 24 hours of infecting the field voles had been found as yet uninfected. The rates of their infection in relation to the number of tick groups grew since the 3rd day of infecting the field voles, and on the 5th-7th day all larvae without exception proved to have taken infection. On the whole, the infection rate in larvae depends on the aggravation of bacteremia in the host, which reaches its height by the time of its death, while in the larvae the infection begins to take root 3 to 4 days earlier.

The larvae engorged 1 or 2 days before the animal donor's death receive *Bacteria tularense* in adequate numbers for transmission during their subsequent metamorphosis to their nymphs. The nymphs and ticks in their turn transmit tularemia microbes when fed on a susceptible healthy animal (transphasic inoculation of microbes to recipients).

If a tick larva feeds on animals slightly susceptible to yet affected with tularemia (2nd group), then it receives few microbes from the donor, should the latter's bacteremia be mild and short-lived; a considerable number of experimental ticks completely eliminate the infection; therefore, its transmission through inoculation by nymphs succeeding molted larvae is exceedingly rare.

The relation of members of one and the same animal species to a microbe pathogenic to them varies with their individual physiological states in connection with changing seasons of the year.

It is characteristic that wild rodents of the temperate climate hibernate, building up fat beforehand. When in a dormant condition,

Fig. 38. The marmot (*Marmota bobac*).

a warm-blooded animal turns into a cold-blooded one, as it were, its body temperature decreasing, heart-beat and respiratory rate becoming slower, etc.

Susliks and marmots also hibernate (Fig. 38); in warm weather, these animals are very liable to be affected with plague which quickly becomes fatal. When getting ready for their winter sleep, they take much food and grow fat. At this time, as also in the dormant condition, they do not develop clinical symptoms when infected with plague, but acquire a latent disease which, as a rule, becomes worse once the animal has awakened (Gaisky, 1926, 1944). A number of Soviet and foreign authors have reported that in tarbagans susceptibility to plague decreases as the hibernation period draws closer. In 1960, A. D. Solodkaya, R. S. Kolesnik, and G. P. Pletnikova (1961) found that in hibernating tarbagans susceptibility to plague microbes decreased, and experimental plague took a latent course. It is probable that the plague microbe itself hibernates inside a dormant marmot, thereby surviving in nature during the interepizootic period.

An important role in virus circulation is played by asymptomatic parasite carriers acting as virus donors, specifically those which harbour pathogenic microbes in their peripheral blood for a fairly long time (virusemia).

The true donors are those animal individuals which harbour infection where it is accessible to vectors, i.e., in the peripheral blood on which biting insects may feed. In a number of animals, however, virusemia may be brief as is the case, for example, with tick-borne encephalitis. Yet the presence of a pathogen in the blood is not enough to infect a blood-sucking insect. A certain minimum titre (amount) of contagion is required to make the infection of a vector possible.

If a neurotropic virus has moved from the blood to the central nervous system, it cannot be acquired by a bloodsucking vector (Zilber, 1945) biting the animal, and the latter no longer takes a direct part in the further circulation of the virus (this would have taken place if the virus, for one reason or other, had left the brain and re-invaded the blood stream. There is no experimental evidence to this effect for any virus).

One can presume the existence of a rather far roundabout route for the circulation of viruses invading the brain as a result of its owner, alive or dead, falling a prey to some flesh-eating vertebrate or insect. Such feeders may be carnivorous and omnivorous mammals, birds of prey, and even carnivorous insects—carabuses. The immediate question is whether alimentary infection of such feeders with a corresponding virus can take place (by a distant analogy with milk-borne encephalitis). One should primarily take into account the influence of the gastric juice on the digestion of the viruliferous organs (brain) of the devoured animal, and, secondly, even if the virus survives it is not known whether the carnivore is susceptible to alimentary virus infection.

The question, or rather a host of questions of this kind, can be given a positive or negative answer upon experiments with various species of carnivores, animals they prey upon, and viruses of variable nature; in other words, there is a vast field for experimenting as well as for the study of such recipients and donors as bats, moles and other animals leading a peculiar way of life.

## THE EFFECTIVENESS AND RESULTS OF VIRUS INFECTION OF MOSQUITO VECTORS

For a vector to contract virus infection on a donor body an adequate degree of infectious virus titre is required, in other words, an adequate infective capacity of the virus present in the blood of the animal donor when vectors are feeding on it.

This conclusion has been drawn by Bárdoš and Jacobic (1961) from an experimental infection of sucking-pigs with Ťahyňa virus.

Female *Aëdes vexans* mosquitoes fed on them subsequently failed to acquire infection. The sucking-pigs had apparently sustained a latent form of the infection, sufficient for forming antibodies neutralizing viruses and reducing hemagglutination.

Consequently, the swine are not a reservoir of the Ťahyňa virus in nature, because they cannot act as virus donors for mosquito vectors in the external environment and sustain virus circulation at a site of mass reproduction of *Aëdes vexans* mosquitoes.

It is interesting to know what happens to a virus once it has entered a vector body. This question should be answered differentially for each particular virus and vector strain.

In some cases, nothing happens to the virus; it does not multiply in the vector body and for a certain time lodges within its mouth parts, specifically in the proboscis where it gained access while the vector was biting the virus donor. Subsequently biting a healthy animal, this vector mechanically conveys the virus, and if the latter has retained its infective power the animal recipient contracts a disease; such mechanical transmission is observed, for example, in smallpox of birds.

In other cases, which are numerous enough, the virus acquired from an animal donor multiplies in the vector body. For example, the "Uganda S" virus ingested with blood from a donor decreases in amount in the mosquito vector body according as the blood is digested in the mosquito stomach; during 4-6 days' observation of infected mosquitoes kept at a temperature of 23°-30° C the amount of virus decreases to a minimum (phase of virus titre reduction), and at this time the mosquito vector is unable to transmit the virus when repeatedly biting a healthy experimental albino mouse. In the meantime, however, the virus penetrates the stomach wall and invades the mosquito body cavity filled with nutritive fluid—the hemolymph—corresponding to the blood and lymph in the vertebrates. The virus begins to multiply in the hemolymph circulating in the mosquito's visceral organs and penetrates some of them, for example, the thoracic salivary glands where it continues to propagate, so that the overall virus titre grows quickly, reaching a maximum in 10-12 days' time.

It is particularly important that in this process the virus gains access to the exit from the insect body, i.e., the salivary glands and their outlet ducts opening out into the stinging mouth parts of the mosquito. Once the virus infection has accumulated in the salivary glands, the mosquito becomes infective to experimental animals and man for the rest of its life. An idea of the virulent material stored in the salivary glands of a mosquito vector can be gained from one example relating to the East American encephalitis virus: according to estimates, the salivary glands of a mosquito vector may harbour as much morbific material as is needed for a lethal infection of a thousand, and sometimes more, albino mice.

It can be seen that in a virus-invaded mosquito body the initial phase of virus titre reduction passes into the phase of an increase and culminates in the phase of virus stabilization, which continues through the mosquito life span.

In this way, the virus harboured in the mosquito body undergoes a kind of a life cycle requiring a definite, fairly high mean temperature of the external environment, the duration of which varies with different virus strains.

Filtrable viruses are not detectible with the common light microscope even at the largest magnification rate, whereas their elementary bodies are rendered visible by special treatment and photography through an electron microscope magnifying many thousand times. Therefore, changes in the virus condition within the vector body leave one wondering whether the virus really undergoes any development or it simply multiplies. Moreover, the very nature of virus is a subject for debate: some consider it to be a sort of degradative derivative from certain microorganisms, while others view it as an evolutional intermediate stage between inorganic and primitive living matter. We share the latter view.

The fate of the tick-borne encephalitis virus in the body of arthropodic vectors, specifically, *Ixodes* ticks, was traced in experiments on albino mice (Pavlovsky and Solovyev, 1940), as has been described above (see pp. 57-61).

## TERMS OF TRANSMISSION BY VECTORS OF INFECTIONS WITH NATURAL FOCI

It is essential to know how long a transmissible disease can be spread by a particular vector.

This question of great epidemiological importance is decided specifically for each particular vector in relation to a particular infective agent. There is no hard and fast rule for all vectors. The answer is provided by various experiments, though the findings from any experiment of a corresponding category cannot be applied to man indiscriminately. Laboratory studies should be carried out along with field observations and experiments, i.e., in account with the influence of the external environment on the mode of disease transmission by a vector.

Turning to evidence in relation to fleas as transmitting agents of the *Bacillus pestis*, it should be noted that not any bite by a flea harbouring plague bacilli blocked in its foregut will infect an animal. One flea can transmit infection to four guinea pigs in one day and to eleven other animals during the subsequent days (Eskey a. Haas, 1939, 1940).

Since both female and male fleas feed on blood both are likely to transmit the plague microbe, though females do it more often than males, approximately in an 11 to 4 proportion.

Many hundreds of flea species are known to science. Different species play a variable role in plague microbe transmission, which depends on a large number of factors. These are (1) the rate of plague microbe propagation in the flea body which involves the clogging of the flea foregut by the agglomeration of plague bacilli growing within it; (2) the duration of the flea's infectivity; (3) the process of spontaneous elimination of plague bacilli from the flea intestine (possibly under the influence of bacteriophage); (4) the frequency of bites by infective fleas; (5) the life span of an infective flea; (6) the behaviour of the flea of a given species; (7) the environmental circumstances, for example, the temperature (certain flea species transmit *B. pestis* at a low temperature, others at a higher temperature). Moreover, fleas of one and the same species have a variable significance in the transmission of plague in different landscape zones, and so forth.

In the U.S.S.R., natural infection with plague has been found in 40 species and subspecies of fleas, and on the worldwide scale it has been found in 180 species (Rall, 1958).

With regard to the term of transmission of other infections by vectors it will be recalled that *Anopheles* females infected with malarial plasmodium can transmit malaria throughout their life, since they repeatedly attack people. Malarial plasmodium sporozoites are not completely eliminated from the salivary glands of the *Anopheles* mosquito.

Lice also retain their capability to transmit *typhus rickettsiae* throughout their life span.

*The tick-borne encephalitis virus* is preserved in the body of a tick vector through the latter's life time, but its transmission to animals by a three-host *Ixodes* tick can take place only three times in the latter's life. This fact is accounted for by the tick's feeding habits.

*Tick-borne relapsing fever spirochetes* can live in *Ornithodoros papillipes* ticks for years. Since these ticks can repeatedly feed in different phases and stages of their metamorphosis, one tick individual may transmit spirochetes to animals and man many times during its life. It feeds quickly and its bite is practically painless to man.

Lice harbouring relapsing fever spirochetes in their body cavity, however, have no natural exit for the microbes. They do not transmit spirochetes when feeding; therefore, an infective louse can communicate disease to man only once in its life provided it has been crushed by scratching the itching parts of the skin.

There is no doubt concerning the transovarial (intrauterine) transmission of *the pappataci fever virus* by sandflies, which has been proved by a special experiment carried out by an expedition of the Department of Parasitology of the U.S.S.R. former All-Union Institute of Experimental Medicine in 1936 and 1937 (Petrishcheva and Alymov, 1939). Many female sandflies were infected on patients

with pappataci fever in Sevastopol. The sandflies were taken to Moscow where they produced a daughter generation. From 40 to 640 females of this generation were fed on 18 volunteers, and sixteen of them fell ill with pappataci fever. The females of this generation could not have acquired the virus otherwise than from their mothers when being in the egg stage inside of them. That the virus is contained in sandfly larvae which do not feed has been proved by infecting two volunteers with an emulsion from 360 larvae passed through Chamberland's porcelain filter. In this experiment, the pappataci fever virus remained in sandfly larvae during 9 months.

During the expedition from the Moscow Institute of Tropical Diseases in 1937, pappataci fever was induced in 5 out of 22 experiments on volunteers infected from a sandfly generation evolved in Moscow from females which had been fed on pappataci fever patients in Sevastopol six and more days before laying eggs (Moshkovsky et al., 1937).

The pappataci fever virus winters in sandfly larvae and pupae, and the first cases of this disease are reported several days after the emergence of sandfly imagoes, which are sensitive to cold, in the second week of June. The incidence of pappataci fever, as evidenced by the earlier findings of our expeditions, begins to decline since the latter half of August, but the time of the advent and subsequent occurrence of this disease is directly related to the macro- and microclimatic conditions which vary with different periods.

## SUSCEPTIBILITY OF DIFFERENT VECTOR SPECIES TO VARIOUS TYPES OF MICROBES

Different species of vectors exhibit variable susceptibility to infection with microbes of different types. Thus, A. A. Volkova, R. V. Grebenyuk, and A. F. Timofeyev (1961) found that the ticks *Dermacentor marginatus* and *D. pavlovskyi* are much more susceptible to melitensis-type *Brucellae*, the *D. pavlovskyi* ticks displaying higher susceptibility, whereas with regard to the bovis-type *Brucellae*, ticks of the same species showed an especially low susceptibility.

Both species of ticks infected with melitensis-type *Brucellae* transmit them to recipients in 90 per cent of cases in experiments, whereas the transmission rate for bovis-type *Brucellae* is only 30.7 per cent. No transovarial transmission of *Br. bovis* by the same two tick species was observed by these authors, whereas *Br. melitensis* was found to be transmitted by this route.

Assuming the existence of natural foci of brucellosis associated with hare hosts, G. A. Kolomakin (1961) supposes that dogs tending flocks of sheep probably contract infection from hares, since in case of the latter being absent in the pasture area brucellosis is not found in sheep dogs. When eating sick hares sheep dogs acquire the infection and subsequently transmit it to sheep.

Experimenting on a vast material (about 7,000 wild animals and more than 20,000 ticks), M. M. Rementsova (1961)* managed to isolate 12 *Brucella* cultures from wild animals and 8 cultures from ticks. Findings positive for *Brucellae* were made near stock-breeding farms hit by brucellosis, whereas in nature this disease occurs but rarely.

## MIGRATION OF VECTORS AND EXPERIENCE WITH ERADICATION OF VECTOR-BORNE DISEASE IN A SPECIFIC GEOGRAPHICAL LOCALITY

Vectors are capable of migration, which may be active or passive. The former is characteristic of winged bloodsucking dipterans, the latter—of ticks and other parasites travelling on their hosts, which sometimes bring them to localities absolutely unfit for their existence. For example, a few years ago, a batch of neat cattle infested by ticks of the genus *Hyalomma* was brought close to Leningrad from the North Caucasus. This migration of ticks was of no consequence because after leaving their hosts the engorged *Hyalomma* ticks were unable to undergo their further life cycle in the climate of Leningrad region. Analogous cases of such ticks being brought to the northern areas by migrating birds are also known.

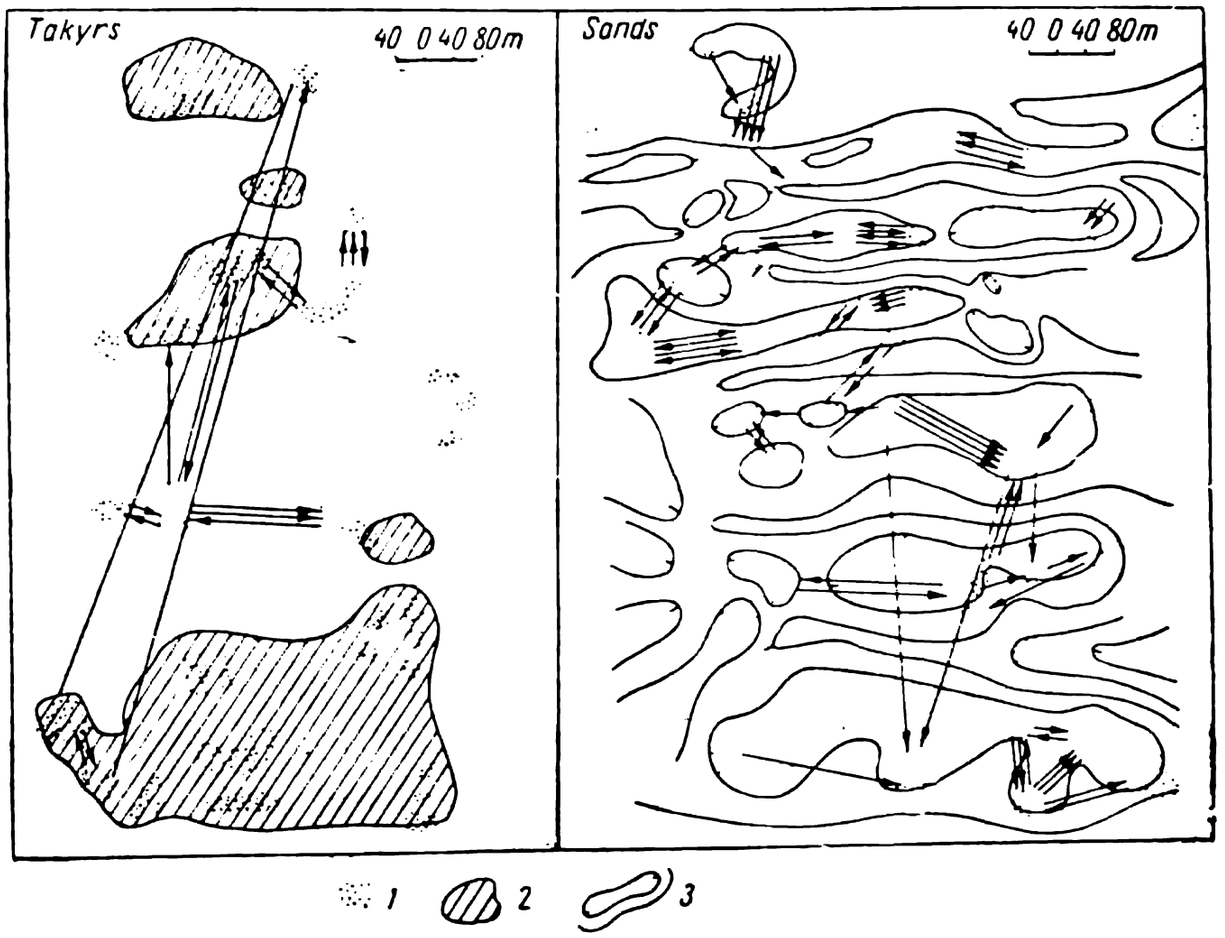
But the passive transference by the host of its ectoparasites—vectors of infection—taking place within the limits of the habitat of a given vector species may have epidemiological and epizootiological significance, for example, rodents migrating from one burrow to another (Figs. 39, 40) may transfer their fleas, both infected with and free from plague bacilli. In this way, this transference may help fleas infest new burrows and acquire new rodent hosts.

In Turkmenia, Penjdeh sore and tick-borne spirochetosis are widespread among gerbils acting as donors of these infections to their vectors—sandflies and *Ornithodoros tartakovskyi* ticks inhabiting their burrows. The entry of gerbils into the burrows of their neighbours also contributes to the formation of a less scattered natural focus of the above-mentioned diseases.

One and the same burrow in a desert may be a focus of the following three diseases: plague, tick-borne relapsing fever, and Penjdeh sore. Such foci are known as *conjugate*. If a gerbil burrow in a hot desert is found to be a breeding place of such tiny and frail-winged dipterans as sandflies it is necessary to trace where and how they undergo their life cycle.

This question is of substantial importance for planning and implementing sandfly control measures in a specific situation. One would

* The monograph *Brucellosis of Wild Animals* by M. M. Rementsova was published in 1962 (Kazakhstan Academy Press, Alma-Ata, 1962).

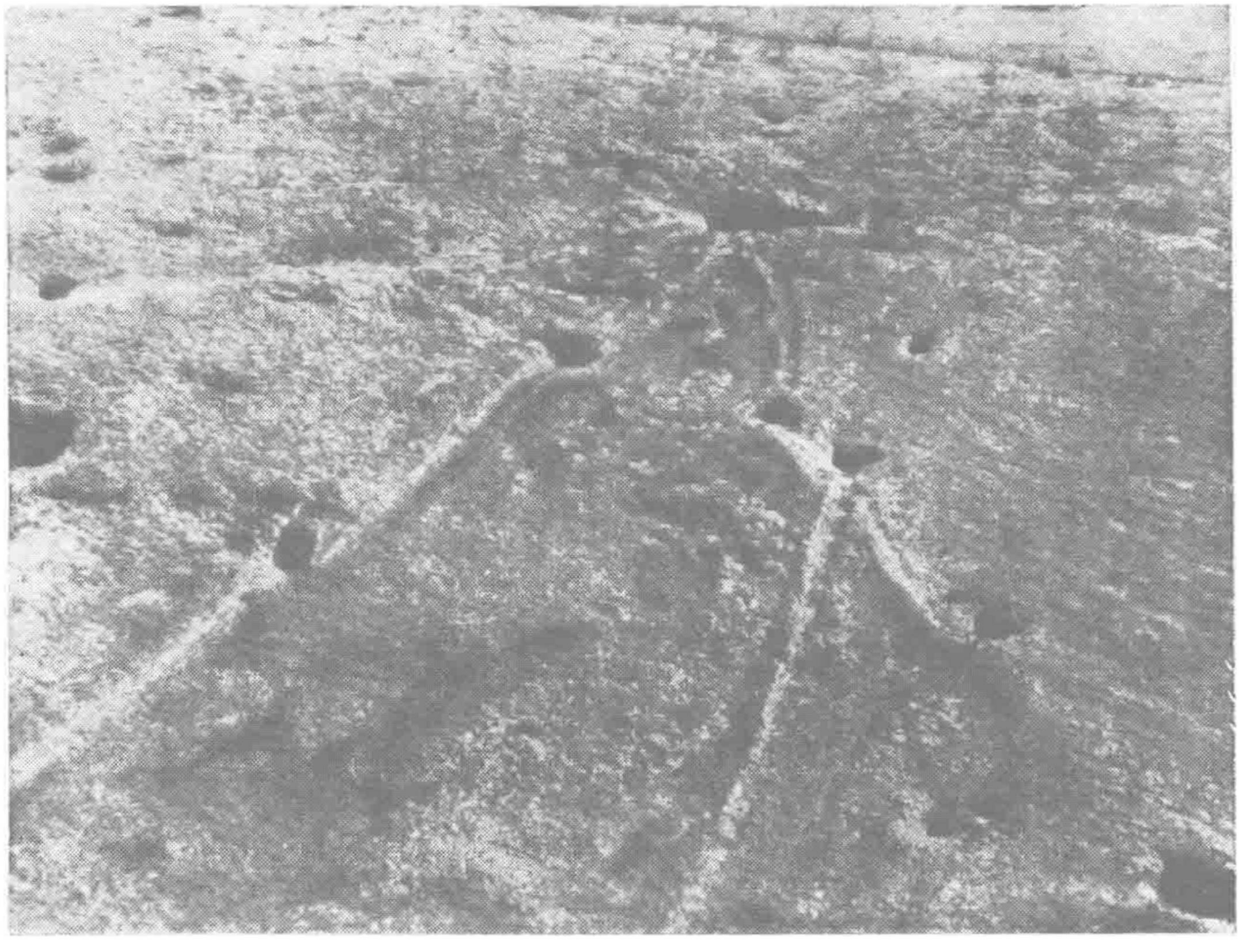



F i g. 39. Migration of labelled large gerbils from burrow to burrow in colonies in sand regions and on takyr soils. According to N. P. Naumov, A. A. Zhuchayev, S. N. Varshavsky, et al., 1959 (1960).

*1*—colonies of large gerbils; *2*—growths of black saksaul; *3*—horizontal lines showing sand relief; arrows showing migration of labelled animals.

think this problem is insoluble. Indeed, how can one measure the distance covered by a given individual sandfly? A simple and ingenious, and above all faithful method has been developed. After numerous observations by expeditions to the southern regions (Central Asia, Trans-Caucasia, the Crimea) and at permanent stations it has been found that sandflies land on and stick to paper sheets covered with castor oil (after Shakhov's suggestion) and hung even outdoors where sandflies are generally encountered and in places near which they may be expected to breed in burrows and appropriate shelters. Still it remains to be ascertained where a sandfly which has landed on this sticky paper has come from.

A method was used for the self-staining of sandflies with aniline dye powder (Moshkovsky and Nosina, 1933; Latyshev and Kryukova, 1941). The narrow end of an oil-lamp glass is inserted into a gerbil burrow. This glass has an expansion gradually passing directly to a narrower, short cylindrical part to be mounted on the metal oil burner. The earth round the glass is scooped up and pressed closely so that sandflies can leave the burrow only through the glass hole. The glass is preliminarily powdered on the inside with aniline dye (green,



F i g. 40. Tracks made by large gerbils migrating from burrow to burrow within a colony. Turkmenia. Photo by P. A. Petrishcheva.

blue, red, etc.). The outer opening of the glass sticking out of the burrow is loosely stoppered with a piece of cottonwool, leaving on one side a narrow outlet whose walls are also powdered with dye of the same colour as on the inner surface of the glass. In this way many burrows are charged with dyes of different colours in order that a sandfly flying out of a burrow by leaps may inevitably catch dye particles sticking between hairs of its integument, legs and wings.

After charging many burrows with different dyes at a given point A, a large number of adhesive paper sheets (in some experiments up to 1,000) are hung on sticks at a distance of up to 1.5 km around the point chosen for the experiment. This work is carried out for days.

Sandflies leaving the burrows at nightfall scatter in the environs and land on adhesive paper sheets. The latter are collected at the end of the experiment and each captured sandfly is moistened with a drop of alcohol. The alcohol taking on colour means that *a given individual* captured on adhesive paper at point B has flown out of a burrow charged with the corresponding dye at point A. It remains to measure the distance from this burrow to point B so as to determine how far this sandfly has travelled.

Such experiments were also made in a densely populated town to determine the distance of possible migration of sandflies under

these conditions. Similar experiments were carried out in the plains of the Crimea and Turkmenian deserts. It was found that *in town sandflies do not fly farther than 25 metres, whereas in an open space they can cover a distance of up to 1,200-1,500 metres.* This migration is to a certain extent influenced by wind, which may slow it down or, on the contrary, speed it up.

The data obtained were laid at the basis of experiments with sandfly control in deserts and semi-deserts (within the framework of measures for Penjdeh sore control in Turkmenia) and in such a large town of the Crimea as Sevastopol which had long been known as a focus of pappataci fever whose virus is transmitted by sandflies also.

It could be presumed from these findings that in towns it was expedient to try and wipe out sandfly nests (in hospitals, dormitories, barracks), whereas their complete eradication on the town-wide scale was a very difficult matter, if not hopeless. If sandflies in town do not fly farther than 25 metres from the place of their experimental release it is to be hoped that their destruction in selected places within a 25-metre radius will not be followed immediately by an invasion by fresh swarms of sandflies. Indeed, the experiments of our expedition (Department of Biology at the Academy of Military Medicine) in 1932-1933 brought about an obvious decrease in pappataci fever incidence in those town quarters where regular sandfly control measures were implemented, whereas in other quarters where such control was non-existent the rate of this disease was on the whole unchanged. We also undertook sandfly control measures in one quarter of Teheran (Iran), near the terminal.

In Turkmenia, the site chosen for an experiment was a hydraulic construction project on the bank of the river Murgab. Sandflies were so numerous that local residents had to use gauze bed-curtains to keep them off. Many workers suffered from Penjdeh sore, and the local medical station daily admitted up to 50 patients. Within a radius of 1,200 m around the construction site about 500,000 gerbil burrows were charged with chloropicrin-moistened sand and closed with earth by the expedition led by N. I. Latyshev (of the former U.S.S.R. All-Union Institute of Experimental Medicine). Such single poisoning killed the burrow host (gerbil), the *Leishmaniae* harboured within its body and the sandfly vectors present in the burrow. A year after such single (!) poisoning the results of the experiments were checked upon by a special commission. The population gave up the use of gauze bed-curtains because sandflies became too few to worry anyone. No fresh cases of the disease were reported among workers, and they stopped their daily visits to the medical station. Only four boys contracted the disease, probably somewhere outside the area treated. Along its periphery, however, gerbils again began to dig holes, but this had no epidemiological consequences in that year.

At the same time, the latter fact suggested a very important conclusion. The experimental *eradication* of a natural focus of Penjdeh

sore was doubtless successful. Yet this was not enough for complete satisfaction. That a natural focus of Penjdeh sore had been wiped out was, of course, beyond all question but one could not disregard the fact that as early as one year later gerbils began to re-invade the area freed from burrows from the periphery, i.e., from the side of the wild desert. Should this process be allowed to take its course such invasion of the cleaned area will continue and the eradicated focus of Penjdeh sore will eventually be restored, since sandflies will again breed in the new burrows and cases of cutaneous leishmaniasis will appear among gerbils.

Consequently, one attempt to eradicate a focus of Penjdeh sore is not enough. It is necessary later *to keep off the disease from this area* by setting up an appropriate service which would control re-invasion by gerbils from the periphery; this is easier and cheaper to do than to repeat the entire complex of measures so as to wipe out a fully restored natural focus of disease. The same principle should be applied in other cases of eradication of transmissible diseases with natural foci.

Depending on their nature, vectors are also capable of migration which with sandflies, for example, is regular and daily in the warm season of the year. It should be noted that sandflies leaving their burrows by nightfall return in the morning not necessarily to their former dwelling but to the nearest burrow they are likely to find on their way. This burrow may be inhabited by a healthy gerbil which is liable to contract Penjdeh sore from infective sandflies and this contributes to an expansion or congestion of the natural focus as a whole.

At night, when flying over open spaces in a semi-desert, infected (as well as uninfected) sandflies may attack people staying the night in the locality and transmit Penjdeh sore to them.

Apparently, something similar to this occurs with fleas. In the steppe, fleas inhabit suslik burrows and can, though not as regularly as sandflies, leave burrows and migrate over the steppe, naturally over much shorter distances as compared to the mile-long flights of sandflies. But on this short route, naturally infected fleas may attack people staying the night in the steppe (it is in place to recall caravans of Ukrainian oxcart drivers) and infect them with plague.

This, perhaps, accounts for the isolated cases of plague contracted in the steppe, far from villages, as was reported from the North Caucasus in 1925 (Tinker and Zenkevich, 1934).

# CHAPTER IV

# DONORS AND RECIPIENTS

## THE GENERAL ROLE OF DONORS AND RECIPIENTS IN THE CIRCULATION OF THE CAUSATIVE AGENTS OF DISEASES WITH NATURAL FOCI

Raising the question of the comparative significance of animal and bird donors and recipients in the circulation of a pathogenic agent in the pathobiocoenosis of a natural disease focus as a factor sustaining the existence of this focus in nature, it should be assumed in advance that this significance varies not only with the systematic position of the donor and recipient (species, race, etc.) but also with one and the same individual. A pathogenic agent can be transmitted to its vector by an animal donor only when it is harboured in the donor's peripheral blood vessels from where the vector can acquire it through a bite.

Therefore, the duration of the agent's presence in the blood (virusemia, bacteremia—Fig. 36) is substantial. Many viruses are neurotropic, i.e., they exhibit a selective attitude to nerve tissue, and from the blood they enter the nerves and pass into and produce a disease of various parts of the central nervous system. This accounts for the paralytic forms of tick-borne encephalitis affecting different muscle systems, for instance, of the shoulder girdle, neck, etc. The virus accumulates in the central nervous system and disappears from the blood stream. The fact that the virus had been present in the blood is evidenced by the appearance in the blood serum of antibodies to a given virus whose various doses are neutralized by corresponding antibodies. But it is not only the presence of virus in the blood that matters. For the virus to be transmitted from donor to recipient the virus titre, i.e., the virulence of the donor's infection, must be high enough. We shall call it the amount of virus in the donor blood for the sake of simplicity.

Following recovery from some obvious diseases with natural foci or from their latent forms, the patient's blood is found to have antibodies neutralizing to a certain extent fresh portions of the same infection entering his body.

Highly important is the lifetime of the antibodies forming in the blood of the infection recipient; it varies with different recipients also.

Thus, human beings, recovered from tick-borne encephalitis apparently retain antibodies to its virus in their blood for the rest of their life. This fact lies at the basis of the retrospective diagnosis of a disease formerly mistaken for another infection. The blood serum from such persons neutralizes in a certain degree the tick-borne encephalitis virus under experimental conditions.

According to K. N. Tokarevich and his collaborators (1961), the mild course taken by Q fever in farm animals accounts for the brief life of antibodies forming in their blood to *Rickettsiae burneti*.

### THE ROLE OF REPTILES AND BIRDS IN VIRUS CIRCULATION

Surveys for the carriers of the causative agents of diseases with natural foci were in the main confined to mammals and birds. A substantial flaw is the very little scope of analogous examinations of reptiles which may be hosts of *Ixodes* ticks and possibly contribute to contagion circulation in natural foci. It should be made certain for this purpose which species of reptiles can be donors and recipients of specific infections.

As regards the role of reptiles as possible reservoirs of tick-borne encephalitis virus, there are suggestions that lizards, snakes and tortoises may occasionally be hosts of *Ixodes* ticks (*Ixodes ricinus*, etc.), which has been reported in the U.S.S.R. also. But no experiments with their infection by viruliferous ticks have so far been carried out. Some indirect reports have come from Czechoslovakia where Grešíková-Kohútova (Grešíková-Kohútova, Albrecht, 1959) managed to induce a disease with clinical symptoms of encephalitis in three green lizards (*Lacerta viridis*) inoculated subcutaneously with a 10 per cent suspension of brain substance from mice infected with tick-borne encephalitis virus. Most of the other lizards taken for the experiments showed no signs of the disease. In the affected lizards, the virus was found in the blood within from 6 hours to 10 days of infection and it proved possible to isolate the virus from their brain between the 10th and the 16th day. Six to seven weeks after infection those lizards in which outward manifestations of disease were lacking were also found to contain virus fighting antibodies in their blood.

This question should also be studied in the Far East where large Schrenk's serpents (measuring one metre and more in length) are rather common. To settle the problem of the role played by reptiles as links in the chain of tick-borne encephalitis virus circulation in a natural focus it is necessary to undertake laboratory experiments with infection of various species of reptiles by viruliferous ticks—larvae, nymphs and female imagoes—taking for experiments those

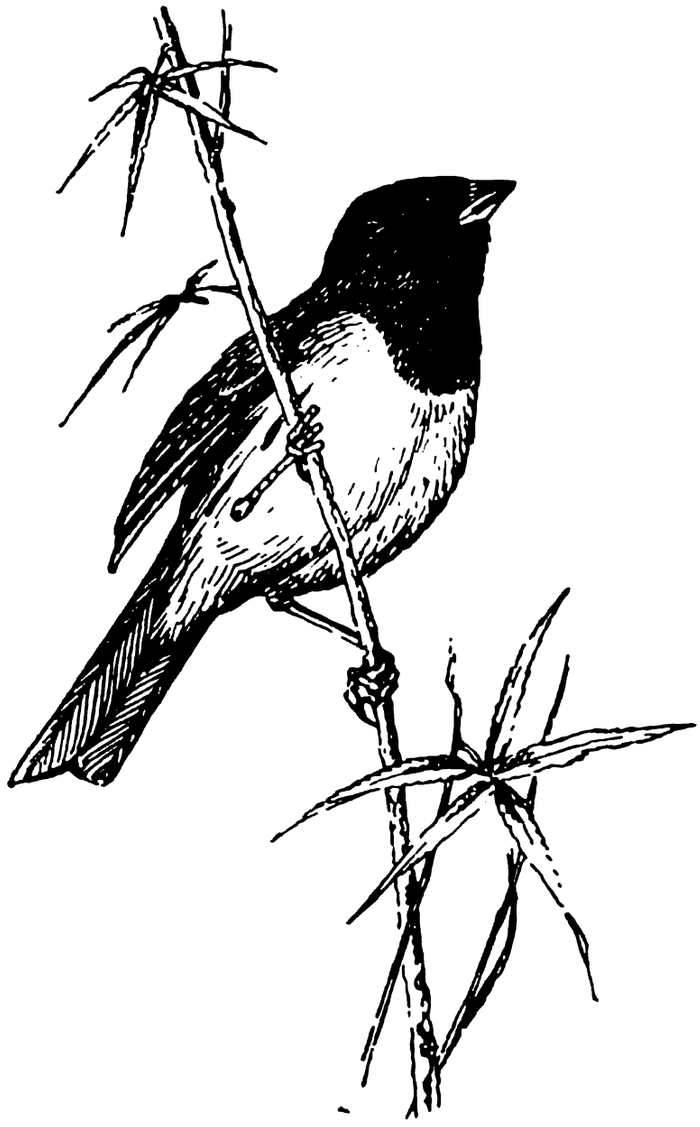


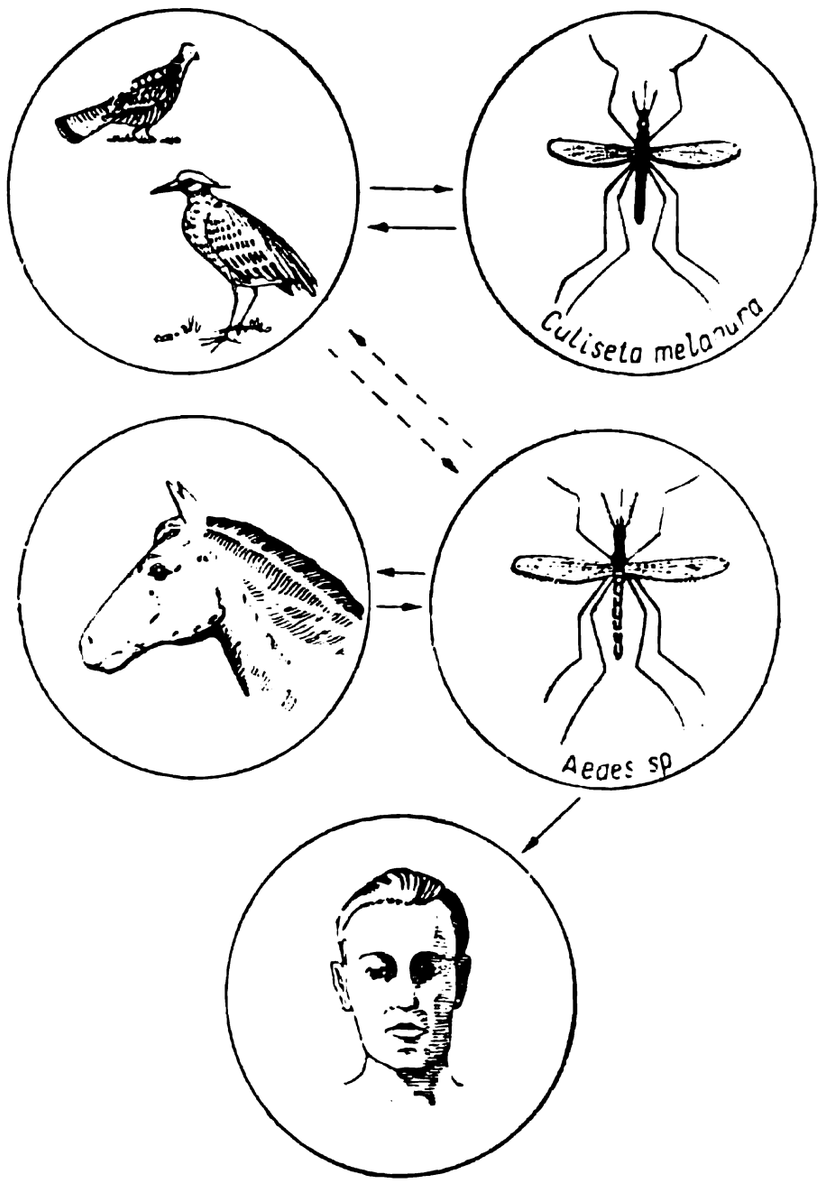
Fig. 41. Bunting *Emberiza rutila*. Drawing by N. Kondakov.

species of reptiles which enter into the composition of the biocoenoses of natural tick-borne encephalitis foci in a specific locality.

In examination of birds, natural infection with the Japanese (mosquito-borne) encephalitis virus was discovered by Shubladze and other researchers in sparrows, pheasants, reed-warblers, yellow buntings (Fig. 41), and in Japan, according to evidence by Mitamura, in sparrows, canary birds, hens, and swallows, which are revered as sacred in Japan and are under special protection.

Certain species of birds can be infected experimentally and also become natural vectors of tick-borne encephalitis virus. These are hazel-grouse, blue thrush, yellow bunting, nuthatch and others (natural infective state—Moskvin, 1940). Similar evidence was simultaneously and independently established for various species of birds by V. D. Solovyev (1941).

Birds nesting on the ground may become tick hosts, and there have been cases of tick-borne encephalitis virus being discovered in the brain of a thrush and in ticks captured on this bird.




F i g. 42. Scheme of circulation routes of the American Eastern encephalomyelitis virus (Eastern encephalitis). According to A. V. Gutsevich (1962).

In nature the principal donors and recipients of the Oriental encephalomyelitis virus in the United States (Oriental encephalitis of the United States) are birds, such as herons, pheasants, sparrows again, pigeons, etc. The virus of this grave disease, though rare in humans, is transmitted by *Theobaldia melanura* mosquitoes belonging to the genus *Culiseta* (Fig. 42).

Avian foci of this disease exist not only in nature but also in villages. These foci, however, may long remain innocuous to man, because the mosquito transmitting this virus apparently is indifferent to humans. Yet another link in the chain of circulation of this virus may be brought into being.

Mosquitoes having preyed on sparrow birds may bite horses and infect them with oriental encephalomyelitis virus. Commonly, sick horses do not become virus donors for mosquitoes since the

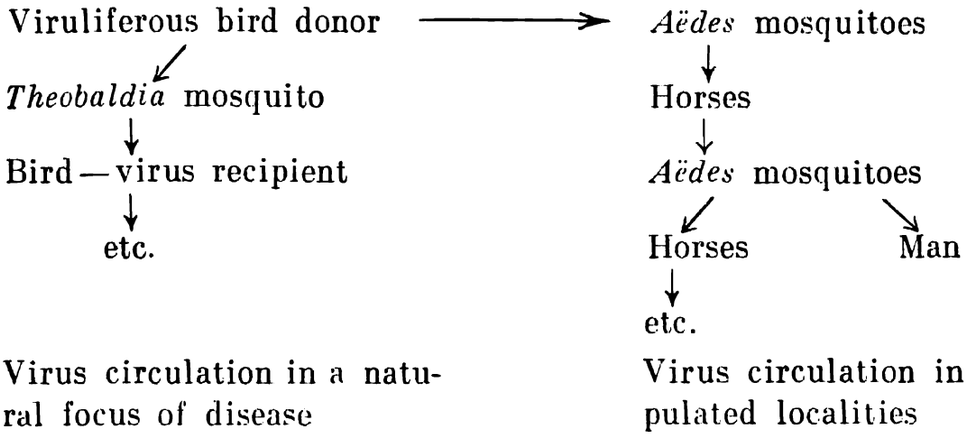
virus titre (amount) in their peripheral blood is not high enough to make mosquitoes attacking them vectors of the virus. But this is the rule. In some cases, however, the virus titre in the blood of sick horses is high enough, at least for the mosquitoes feeding on them, to convey the virus to healthy horses and ultimately to man. Such mosquitoes spreading the virus among horses belong to various species of the genus *Aëdes*, for example *Aë. vexans*, etc. Mosquitoes of the genus *Aëdes* breed in tremendous numbers in the swamps along the Atlantic coast of North America.

Owing to the large size of its body a sick horse attracts swarms of mosquitoes. Having acquired the now horse-borne virus of encephalomyelitis, *Aëdes* mosquitoes may also attack man and infect him with this disease which proves fatal in almost half of the cases.

Consequently, the transmission of this virus to man occurs by a collateral route (see also Fig. 42):

**Encephalomyelitis of Horses**

(Equine encephalomyelitis)




Even with such sequence of virus transmission not every man infected from a viruliferous mosquito necessarily falls ill, which is also observed among human beings infected with viruses of other transmissible diseases, examples of which have already been given (see p. 78).

## THE IMPORTANCE OF THE SPECIES AND AGE OF RECIPIENTS IN THEIR INFECTION WITH VIRUS AND OTHER AGENTS OF DISEASES WITH NATURAL FOCI

The species and age of the recipients of infections and invasions are also factors of substantial significance.

Adult albino rats did not perish after their brain had been infected with a 0.06 mg dose of a 10 per cent Ťahyňa virus suspension, yet they were found to have an inapparent infection causing the formation of virus-fighting antibodies (Bárdoš, Danielová, 1959). Adult Syrian

hamsters, however, died 8-9 days after their identical infection with a Ťahyňa virus suspension. Adult guinea pigs and rabbits proved resistant to an intracerebral injection of a 10 per cent Ťahyňa virus suspension in a double and triple dose and were found to produce virus-fighting antibodies (Bárdoš, Čupkova, Šefčovičová, 1961).

Bárdoš and his collaborators have drawn the conclusion on the need for a detailed study of the febrile diseases with a mysterious cause found in infants living in localities heavily infested by mosquitoes so as "to expose clinical symptoms typical of diseases caused by the Ťahyňa virus" (idem, p. 98).

This conclusion has also been prompted by the fact that antibodies to the Ťahyňa virus were discovered by Bárdoš in the blood serum of residents of Czechoslovakia, Hungary, Albania, Yugoslavia, Italy, and Uganda and in domestic animals in Bulgaria. Such antibodies were found in 30-45 per cent of sera taken at random in places where mosquitoes annually breed in large numbers.

Ever new viruses (arborviruses) * are found in various mosquito species in different parts of the world; it is clear, therefore, that their detailed study takes time and requires a favourable situation, both in the laboratory and the external environment. Therefore, it is unwise to attribute the viruses to a particular known or a new group at the time of their detection in vectors, in bloodsucking mosquitoes in particular, and such new viruses are provisionally named after the geographical locality where they have been initially discovered. For example, the above-mentioned Ťahyňa virus takes its name from a village in Eastern Slovakia where *Aëdes vexans* and *Aë. caspius* mosquitoes infected with this virus were found for the first time.

P. A. Glushchenko, A. V. Gutsevich and M. S. Dudkina (1957), while studying mosquitoes in the Southern Ukraine, more than once isolated viruses pathogenic for albino mice and other animals and belonging to the group of agents of lymphocytic choriomeningitis, a comparatively little studied disease occurring in various countries.

In Africa, in North-Western Uganda, as well as in Kenya and the Congo, a formerly unknown disease, nyong-nyong, was discovered in 1959; it quickly became epidemic and was registered in some 750,000 cases. The virus causing this disease was isolated from two species of malarial mosquitoes—*Anopheles funestus* and *A. gambiae* (Haddow, Davies, Walker, 1960).

It is interesting and instructive to observe the biological differences between these species of malarial mosquitoes. Thus, there is a marked difference and even contrast in the seasonal prevalence of *A. gambiae* and *A. funestus* in one of their habitats. The maximum

* *Arborviruses*—viruses transmitted by arthropods.

prevalence of *A. gambiae* is observed at the time when that of *A. funestus* is at the lowest. Since both of these mosquito species transmit the nyong-nyong virus, the contrarywise fluctuations in their specific prevalence account for the constant presence of one of them. Perhaps, this is also the cause of the high rate of this infection among humans.

It is also interesting to compare the influence of the constant relative humidity (in laboratory conditions) and the variable relative humidity in the external environment on the reproductive capacity of *A. gambiae* females. Here are the results of one experiment. Mosquitoes were hatched from pupae on December 20, 1948, kept in isolation since December 25, and from December 26 through January 20, 1949, were kept in a laboratory at 82.4 per cent relative humidity. One of the females deposited the following numbers of eggs:

| | | |
|---|---|---|
| First oviposition | January 15, 1949 | 84 eggs |
| Second oviposition | January 18, 1949 | 212 eggs |
| Third oviposition | January 20, 1949 | 103 eggs |
| Fourth oviposition | January 23, 1949 | 77 eggs |
| Died | January 26, 1949 | |
| | Total | 476 eggs |

From January through May in the same year 1949 the relative humidity in the external environment fluctuated within a range of 30.4 to 82.2 per cent being 53.4 per cent on the average. During this period, the female deposited eggs only on two occasions:

| | | |
|---|---|---|
| First oviposition | April 16 | 162 eggs |
| Second oviposition | May 16 | 70 eggs |
| Died | May 22 | |

The difference between these two observations is staggering.

## THE DIFFERENCE BETWEEN THE SPECIFIC AND SEASONAL SUSCEPTIBILITY OF RECIPIENTS TO PATHOGENIC AGENTS ON THE EXAMPLES OF PLAGUE AND OTHER DISEASES WITH NATURAL FOCI

E. I. Klets, Z. I. Shchekunova and Z. F. Padalko (1959) in experimental infection of animals found the highest susceptibility to plague in the rat-like hamster and in the harvest mouse (Fig. 43), whereas the Asiatic, forest (Fig. 44) and field mouse, as well as the field vole—Eastern and red-gray—proved slightly susceptible to this disease. The black rat and the house mouse showed a fairly high susceptibility, whereas the grey rat was found to have high resistance to experimental plague. The authors carried out studies in the Far Eastern

Fig. 43. The harvest mouse *Micromys minutus*.

Fig. 44. The forest mouse.

Maritime Territory on a virulent strain of the plague microbe isolated from tarabagans in 1955. The virulence of the strain was verified before the experiments, the animals being infected by subcutaneous injections.

The susceptibility to plague in tarabagans and long-tailed susliks is subject to seasonal variations, decreasing from spring towards autumn. They are the most susceptible in April and May after the end of their hibernation. Following their awakening the infective dose for susliks is less than 20 microbial bodies, and for tarabagans 73; in the autumn, however, the dose for tarabagans is 14,470, and for susliks 1,225 microbial bodies. In spring, susliks, just as guinea pigs, perish from plague on the 48th day, in summer 2-3 days later, while in autumn certain individuals die as early as on the 19th and 22nd day.

In summer, isolated cases of chronic plague are found in tarabagans, the virulence of the microbe being drastically attenuated (Olkova and Smirnova, 1959).

In the Daur suslik experimental plague runs an acute course in summer time, and septicemia develops early: this is a prevailing rather than absolute phenomenon, which may be accounted for by the variable susceptibility of animals in summer (Gaisky, 1944; Nekipelov, 1952; Kolesnik and Pletnikova, 1959).

Different animal species have variable susceptibility also to other diseases with natural foci. For example, wolf-cubs (*Canis lupus*) develop tick-borne encephalitis with all its characteristic symptoms, whereas dogs (*C. familiaris*) are resistant to it.

## AGE AND SEASONAL CHANGES IN THE PHYSIOLOGICAL CONDITION OF MAMMALIAN RECIPIENTS OF AGENTS OF DISEASES WITH NATURAL FOCI

That the physiological state of the animal body changes with advancement in age and with seasons of the year is graphically illustrated by the variations in the susceptibility of little marmots to zinc phosphide, which is generally poisonous to them (Nikitina, Kucheruk, and Rozhkov, 1955). Zinc phosphide is used for poison baits in pest control operations. From early spring up to the time when rodents begin to hibernate their susceptibility to this poison increases. Adult females are generally more susceptible than adult males, while young animals are much more susceptible than adults. The cause of such changes is precisely the difference in the physiological states of these animals.

The fact that the age variations in the physiological state of the animal body are some of the most important ones has been noted by other authors also (Tinker and Kalabukhov, 1934; Aparin, Tereshchenko, 1959, et al.).

The age susceptibility to plague combines with seasonal predisposition. Thus, in *young* guinea pigs susceptibility to the *Bacillus pestis noticeably declines in winter and considerably increases in summer*. In 1-2-day-old guinea pigs plague runs a very fast course, whereas in 20-21- and 25-29-day-old animals the disease continues much longer. Young guinea pigs vaccinated against plague develop a less stable immunity than adult animals.

Older albino mice are much more resistant to infection with plague than middle-aged individuals (Aparin, Tereshchenko, 1959).

It is not always possible to isolate tick-borne encephalitis virus from the brain of wild animals containing virus-fighting antibodies in their blood. This was the case in particular in Slovenia (Yugoslavia) in experiments made by V. Bárboš, B. Rosický (Prague), and I. Vesenjak-Zmijanac (Zagreb), which the authors attributed to the hot tropical weather prevailing in the spring of 1957, and to the fact that the animals were captured in the Yugoslavian Alps late in June and early in July 1957 when the weather was also extremely hot there. Evidently, the capturing time was late, and the brain of captured animals no longer contained tick-borne encephalitis virus. Yet in their opinion, the detection of virus-fighting antibodies in the blood is adequate proof of the existence in Slovenia of natural foci of tick-borne encephalitis in which virus circulation occurs with the same regularity as in Czechoslovakia (Bárdoš, Rosický, Vesenjak-Zmijanac, 1959). This conclusion is perfectly cogent for the mere fact that the formation of virus-fighting antibodies in the blood of rodents is a reaction to virus *invasion*. And in wild nature this invasion occurs as a result of viruliferous ticks attacking their hosts.

But ticks also attack in numbers animals with antibodies already present in their blood (immune blood). When a viruliferous tick is drawing such blood the amount of virus in the tick body decreases as a result of a part of the earlier received virus infection being neutralized in vivo. When viruliferous ticks had their meal of blood on immune animals, the latter did not develop virusemia and the virus was not eliminated with their milk (Grešíková, 1958; Blaškovič, 1959). On these ground Blaškovič assumes that in territories with natural foci of tick-borne encephalitis on pastureland domestic animals should be vaccinated, since this measure will contribute to a reduction of the rate of this disease among humans.

It is important to know whether the virus is eliminated from the body into the external environment and if so, what epidemiological significance this has.

It has been found (Levkovic, Drobyshevskaya, Chervyakov and Neustroyev, 1941) that the tick-borne encephalitis virus is eliminated in negligible doses with nasopharyngeal mucus and urine by sufferers from this disease. This can be proved only by prolonged passages through albino mice, which gives one reason to question the epidemiological significance of this phenomenon.

In infected female albino mice negligible virus doses are eliminated with the urine and may be also found in the nasopharynx. When such mice are kept together with healthy albino mice, the latter do not contract the infection and fail to develop immunity against this virus; therefore, its elimination in such small doses has no epizootiological importance either.

During the past few years, there have been ever frequent reports of cases of milk-borne encephalitis. Cases are also known of familial infection due to *raw* goat's milk consumed by all members of a family. The milk will contain the virus of this disease if the milking goat has a latent infection. When milking such a goat the virus is eliminated with milk from its body and, once it has entered the human stomach, it causes an alimentary infection. The cow does not eliminate the virus with milk and its use for food is harmless to humans.

In cases of milk-borne encephalitis the transmitting agent is also the very same *Ixodes* tick. Indeed, how can a goat receive a virus? Only through a tick bite. The further migration of the virus from such a goat to man takes place by the alimentary route—through virus-infected raw goat's milk.

Nursing mothers suffering from two-stage encephalitis have no virus in their milk and cannot, therefore, infect their breast-fed babies. Sick humans practically eliminate no virus into the external environment, which fact is of substantial import in consideration of the epidemiology of tick-borne and two-wave encephalitis. Goat's milk, however, may be the cause of tick-borne encephalitis, its paralytic form in particular (Levkovic, 1959).

Over the past few years, cases of tick-borne encephalitis exclusively due to goat's milk were noted in one of the districts of the Kirov Region. The presence of the virus causing this disease was determined by the complement fixation test (CFT) in goats and cows. It is interesting that the percentage of its positive results in cows was twice as large as in goats. Cases of milk-borne encephalitis due to cow's milk were not found at all, even in the owners (and members of their families) of those cows in which the CFT had proved positive; this reaction was negative in the cow owners themselves and in members of their families. It follows that neither the immediate presence of cows harbouring tick-borne encephalitis virus nor the use of their milk for food had any epidemiological consequences. The principal cause of diseases is attributed to raw goat's milk (Dravert et al., 1961).

In the Khabarovsk territory, cases of alimentary infection with tick-borne encephalitis, according to evidence by A. A. Veret, are increasingly frequent. Thus, of the total number of cases of this disease in 1957 the alimentary infection through goat's milk accounted for 2.9 per cent, and in 1958 for 6.1 per cent. It was also noted that as distinct from analogous cases of this disease in the West milk-borne encephalitis runs a severe course with a high death-rate

in the Khabarovsk territory. When experimenting with intramuscular and subcutaneous inoculation of goats with tick-borne encephalitis virus recovered from ticks collected in one of the foci of the Khabarovsk territory, the virus was found both in goat's blood and milk. Samples of this milk as well as milk from healthy cows and goats in winter were found to contain an inapparent blood admixture (N. I. Markevich). It can be presumed, therefore, that it is precisely this admixture of virus-infected blood that accounts for the presence of virus in the milk of farm animals.

Experiments, however, with subcutaneous injection of tick-borne encephalitis virus to goats, sheep and cows and its subsequent discovery in their milk should not be directly identified with infection of animals in nature when they are bitten by viruliferous ticks.

G. K. Gilmanova and Y. S. Gubaidullin (1959) advanced this proposition on the basis of their experiment carried out in natural (not laboratory) surroundings. Eight goats had been brought from districts with no foci of tick-borne encephalitis, and were pastured since May 20 for a month in two areas having natural foci of this disease (in earlier years, paralytic forms of tick-borne encephalitis has been observed in these foci). The milk of these goats was found to contain tick-borne encephalitis virus after they had been bitten by 11 to 38 *Ixodes persulcatus* tick vectors.

Moreover, tick-borne encephalitis virus was recovered from the offspring of ticks which had fed on the goats. The viruses recovered from goat's milk and from *I. persulcatus* larvae (daughter generation from female ticks fed on goats) proved identical for their biological characteristics to the standard sample of tick-borne encephalitis virus.

## THE SUSCEPTIBILITY OF DIFFERENT SPECIES OF RECIPIENTS TO DISEASES WITH NATURAL FOCI

Different species of recipients show variable susceptibility not only to different pathogens but even to one and the same disease (Fig. 45). This is evidenced by experiments on wild and laboratory animals used to study the properties of a specific contagion. Here are some concrete examples. M. M. Rementsova (1961) found in numerous experiments that twelve species of wild animals were susceptible to *Brucellae* (*Br. melitensis*). Particularly susceptible were susliks (*Citellus pygmaeus* and *C. intermedius*) which could be infected with only 10 microbes inoculated subcutaneously. The brucellosis agent itself remains in the body of various species of infected animals for 40 to 245 days, and in the suslik (*C. intermedius*) even for 740 days, the microbes recovered after this period retaining their virulence.

The duration of the presence of *Brucellae* in certain infected animals depends on the rate of spontaneous elimination of the microbes. This, in particular, is especially characteristic of the large

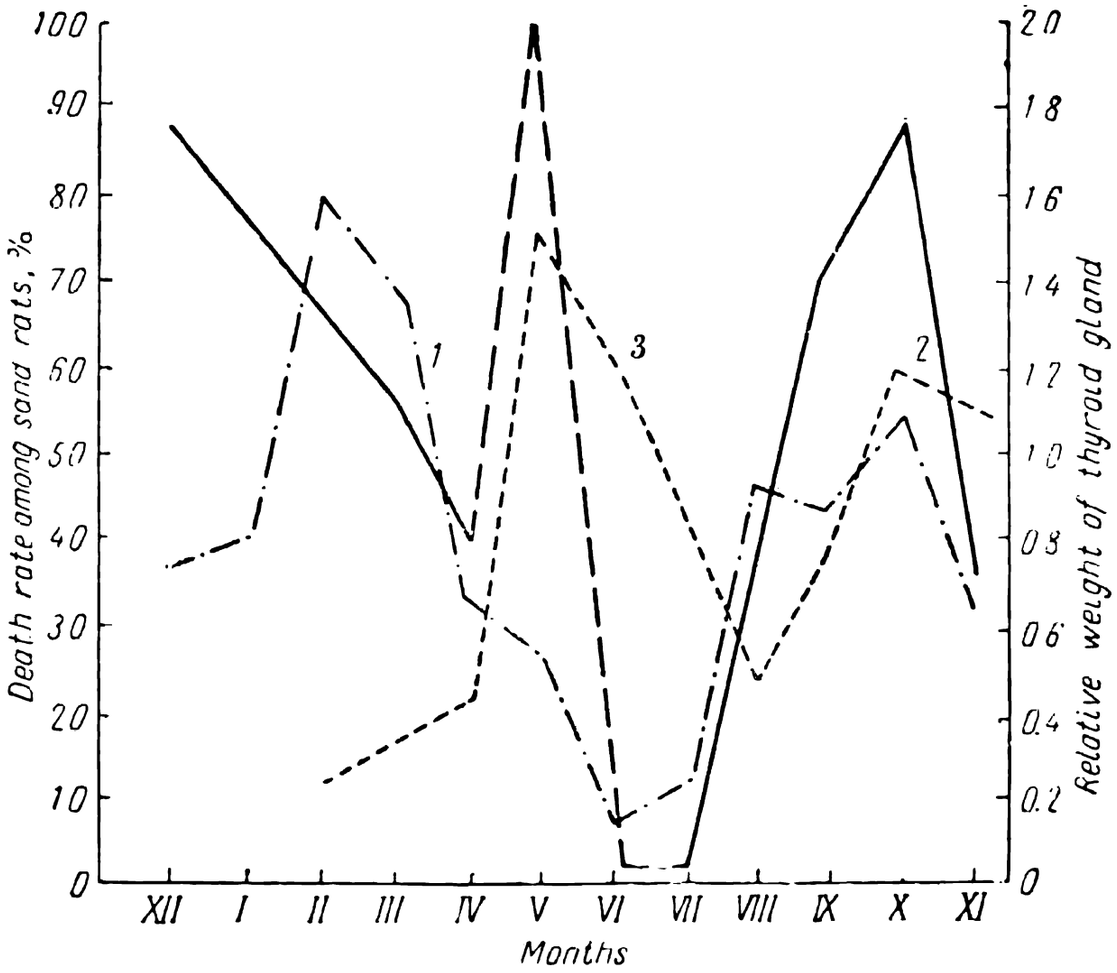



Fig. 45. Monthly changes in the plague susceptibility of large gerbils in Turkmenia upon their infection with a dose of 500 million microbial bodies of a virulent strain culture. According to A. N. Akiev and I. I. Vologina (1960).

*1*—rate of death of large gerbils due to plague verified bacteriologically; *2*—number of rats killed by a generalized infectious process in proportion to the total death rate; *3*—seasonal changes in the weight of the thyroid gland in large gerbils (according to data for preceding year).

gerbil (in which the course of brucellosis resembles that in albino rats) whose body is completely cleansed from this infection within 2 or 3 months. Hares are also susceptible to brucellosis, and microbes recovered from them have an even greater virulence than that indicated above, the least infective dose being only *five* microbial bodies (Rementsova, 1961).

Of substantial importance is the detection of the sources and routes of infection of recipients from a natural focus under specific circumstances contributing to disease outbreaks. The causes may be quite variable. For example, in susliks the plague infection almost exclusively enters through the skin (in a north-western focus of the Caspian region). This accounts for the predomination of the bubonic (September) forms of plague transmitted by fleas.

CHAPTER V

# CERTAIN DISEASES WITH NATURAL FOCI

## TULAREMIA, ITS CAUSATIVE AGENT, THE CAUSES (AND CHARACTER) OF TULAREMIA OUTBREAKS, AND TYPES OF ITS NATURAL FOCI

Many bacteria pathogenic for animals and man may for different periods survive in the external environment which in such cases may be a direct source of human infections. The causative agent of tularemia is particularly interesting in this respect.

In addition to progress made in fighting such an old disease as plague which formerly hit villages and spread like brushfire, an appreciable success has been achieved in the control of a younger disease known as tularemia (plague-like lymphadenitis). This success is thrown into greater relief against the background of some general information on this disease which will be in point here although its name has more than once been mentioned above. Tularemia was for the first time identified as a disease and set apart as a nosological unit in the United States after its causative agent had been discovered in *Citellus beecheyi* gophers in California by McCoy (1911) and Chapin (1912) in 1910-1911. This disease takes its name from the locality called Tularia, where it was discovered. The subsequent events took a fast course: Chapin himself contracted tularemia while studying isolated microbes of this disease, and in the same year (1910) cases were reported of farmers in the State of Utah being afflicted with a disease which common folk attributed to bites of a minute species of the *Chrysops* aphis lion and called it deer-fly fever. From the blood and bubo pus of tularemia patients Francis recovered a microbe which was identified as the *B. tularense* already known to occur in gophers. The reservoirs of this infection were hares and the vectors were gadflies. The disease was widespread in the United States, a total of 20,980 cases being reported over twenty years since 1936. On the world-wide scale tularemia proved to be a disease of the Northern hemisphere, including the U.S.S.R., where it was identified as such for the first time in 1926 by S. V. Suvorov, A. A. Volferts and M. M. Voronkova (1928). This disease early attract-

ed the interest of medical men, zoologists, and parasitologists, so that by the end of 1960 1,300 scientific papers on tularemia had been published and 11 Doctor's and about 60 Master's theses maintained in the U.S.S.R. alone [Olsufyev, 1959 (1960)].

In the Soviet Union, tularemia research went hand in hand with the establishment and development of a wide network of tularemia-control centres whose personnel and medical workers in only 25 years of scientific and practical work secured a reduction in tularemia incidence, which "during the past nine years (1951-1959) fell to a point where it was 21 times less on the average than the rates for the preceding six years (1945-1950)" [Olsufyev, 1959 (1960) p. 418].

It was found from retrospective diagnoses that tularemia in the United States was not in effect a new disease; its fatal cases were with good reason traced back to 1904 and 1907. This disease was new only to medical practitioners who learned to identify it as late as the 'thirties of the current century (recall a similar discovery of a "new" disease, tick-borne encephalitis, in the U.S.S.R.).

Tularemia is a remarkable disease for the number of infection sources, for the host of species of animal donors, recipients and vectors of its causative agent, as well as for the range of prevalence extending to a number of landscape belts, and for the variety of types of its natural foci.

As far back as 1937 Francis in the United States differentiated the variety of circumstances in which people contract tularemia. This most commonly occurs when skinning hares, cutting, cooking and eating their meat. He put the number of such cases at 1,500; more than a hundred cases were due to tick bites, scores to gadfly bites, and a few to contact with sheep (in particular when slaughtering them). Also there were quite a few cases of laboratory infection and infections of which the routes of entry were not exactly identified.

But the U.S.S.R. has gained priority in discovering natural foci of tularemia and, consequently, in classifying it among the group of diseases with natural foci.

The extensive research carried out by Soviet investigators has made it possible to clarify the major features of the geographical distribution of natural foci of tularemia in the Soviet Union, identify the basic species of vertebrate and invertebrate animals sustaining *B. tularense* circulation in nature (i.e., supporting the existence of its natural foci), establish the regularities of the epizootic process, outline the ways of eradicating such natural foci, etc. An important achievement was the elaboration of biocoenological, epizootiological and epidemiological data for classifying the types of natural foci of tularemia, which has enabled a differential approach to epidemiological prognostication and the development of a system of measures for wiping out these foci (*Tularemia*, 1960, p. 206).

In this connection, special notice is deserved by the causes and character of tularemia outbreaks (incidence) in the U.S.S.R., a survey of which is given in the above monograph.

### THE TYPES OF TULAREMIA OUTBREAKS

The following types of tularemia outbreaks are known:

(1) transmissible outbreaks in which man receives *B. tularense* from vectors—*Ixodes* ticks, gadflies, mosquitoes;

(2) outbreaks associated with water rat (Figs. 46, 47, 48), muskrat and hamster trapping;

(3) outbreaks due to hunting hares and their use for food;

(4) outbreaks due to water-borne infections spreading from streams and other open-air reservoirs polluted by water rats, as well as from wells contaminated by house mice and common voles;

(5) agricultural outbreaks due to handling stacks and sheaves of straw (Figs. 43, 49) inhabited by common voles and mice, particularly in the years of heavy mouse invasions;

(6) household outbreaks;

(7) outbreaks due to the use of foodstuffs contaminated with feces of tularemia-affected house mice;

(8) occupational outbreaks, associated with the processing of farm produce, slaughtering livestock, and dressing out meat;

(9) trench outbreaks (in wartime).

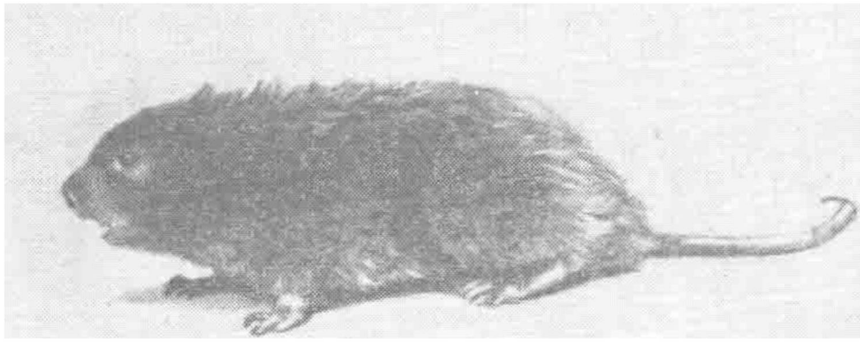
Conformably to the type of outbreak the disease afflicts different population groups, humans being generally susceptible to infection irrespective of sex and age, even though the sick do not convey the infection to the well even by direct contact.

### TRANSMISSIBLE OUTBREAKS OF TULAREMIA. ITS VECTORS — TICKS AND GADFLIES

Transmissible outbreaks of tularemia occur in places near which mosquitoes and gadflies breed or on pastures where people are liable to be attacked by *Ixodes* ticks infected from animals, for instance in ravines (Figs. 50, 51, 52), flood-lands and on the beds (or on the banks) of spring streams (Fig. 53) inhabited by water rats. The infection is most frequently caught when mowing grass and stacking hay, tending a vegetable garden, doing a technical job in land-reclamation, extracting peat, fishing, during a spring-flood (Fig. 54), etc.

Transmissible outbreaks occur only in the warm season of the year when a particular locality is infested by insect vectors likely to bite man. Monthly variations of this period depend on the latitude of the locality. Generally, cases of the disease begin to occur in June or July and end not later than early in October.

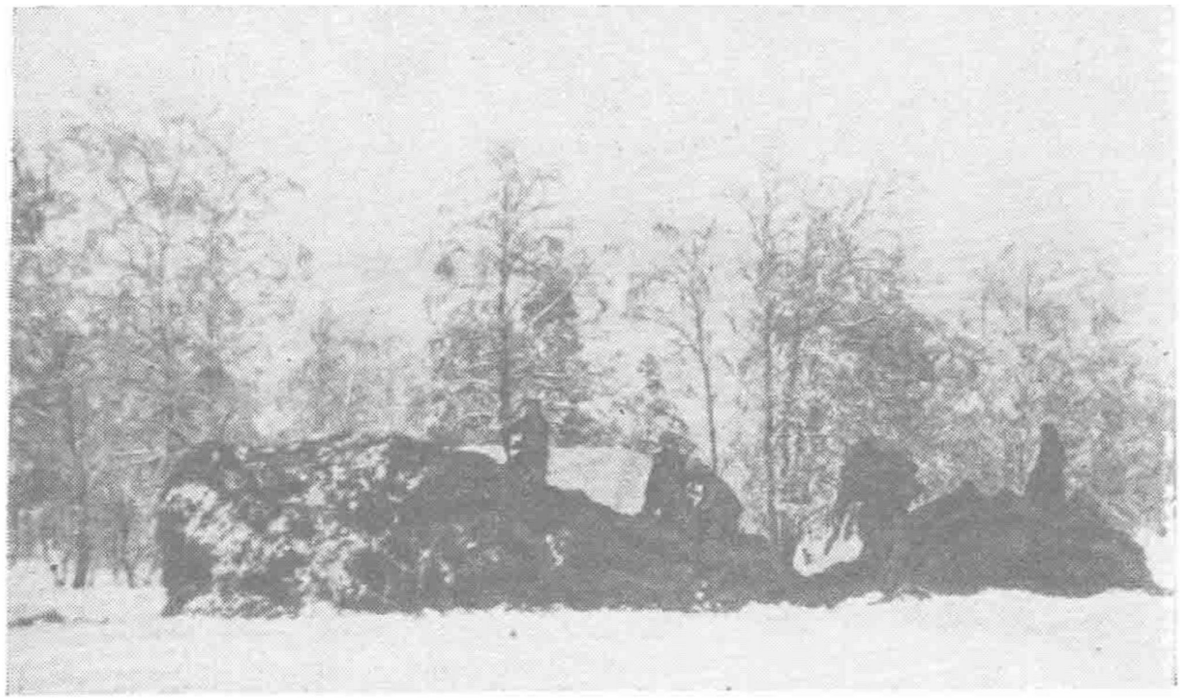
As distinct from the United States cases of contracting tularemia from *Ixodes* ticks in the U.S.S.R. are few. Its vectors in the U.S.S.R.



F i g. 46. The water rat (field vole)—*Arvicola terrestris.*

F i g. 47. A water rat during a spring flood in the Volga delta. Astrakhan game preserve. Photo by N. D. Mitrofanov.

F i g. 48. The trapping of water rats. Alma-Ata.



F i g. 49. Sorting of hay stacks. Photo by N. G. Olsufyev.

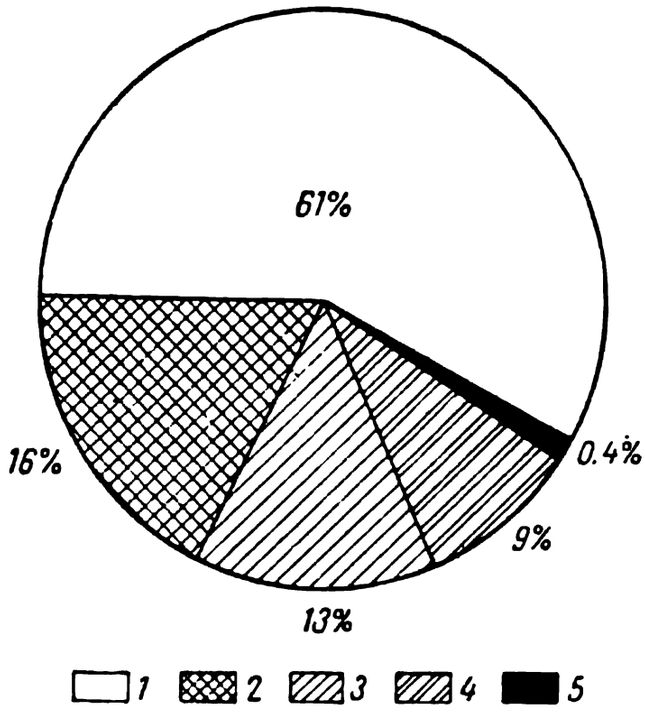



Fig. 50. Distribution of human tularemia cases (per cent) in the southern part of the Moscow region according to the conditions of infection and routes of transmission. From monograph *Tularemia* (1960) by N. G. Olsufyev and G. P. Rudnev.

*1*—winter thrashing of grain crops; *2*—other agricultural jobs; *3*—water; *4*—other circumstances; *5*—ticks and dipterans.

are *Dermacentor pictus*, *D. marginatus*, *Ixodes ricinus*, and *Rhipicephalus rossicus*. Tick-borne infections occur in places infested by hungry ticks, in particular at timber-felling sites and at cattle pastures in forest glades.

Tularemia may be contracted through transmission by any human being regardless of his or her age and profession when being present in an area infested by winged bloodsucking dipterans—mosquitoes or gadflies—and bitten by a naturally-infected insect. This is, of course, a matter of accident, and chances of such infection during a single visit to an infested area are few; yet in case of repeated and prolonged presence (or work) in such areas the hazards of exposure to infected insects increase many times over. Therefore, the incidence of tularemia may grow from isolated cases to a fairly large scale, i.e., become truly occupational and seasonal outbreaks among farm workers.

The transmission of tularemia by its vectors varies in character with the number of times they feed on donor blood, which may take place very seldom or, on the contrary, quite frequently. In this respect, *Ixodes* ticks differ substantially from bloodsucking mosquitoes or gadflies. *Ixodes* ticks feed in the stages of larva, nymph and imago, once in each stage but for a long time (sometimes for a few days running). The engorged six-footed larva after a certain time transforms into an eight-footed nymph still lacking the genital pore.

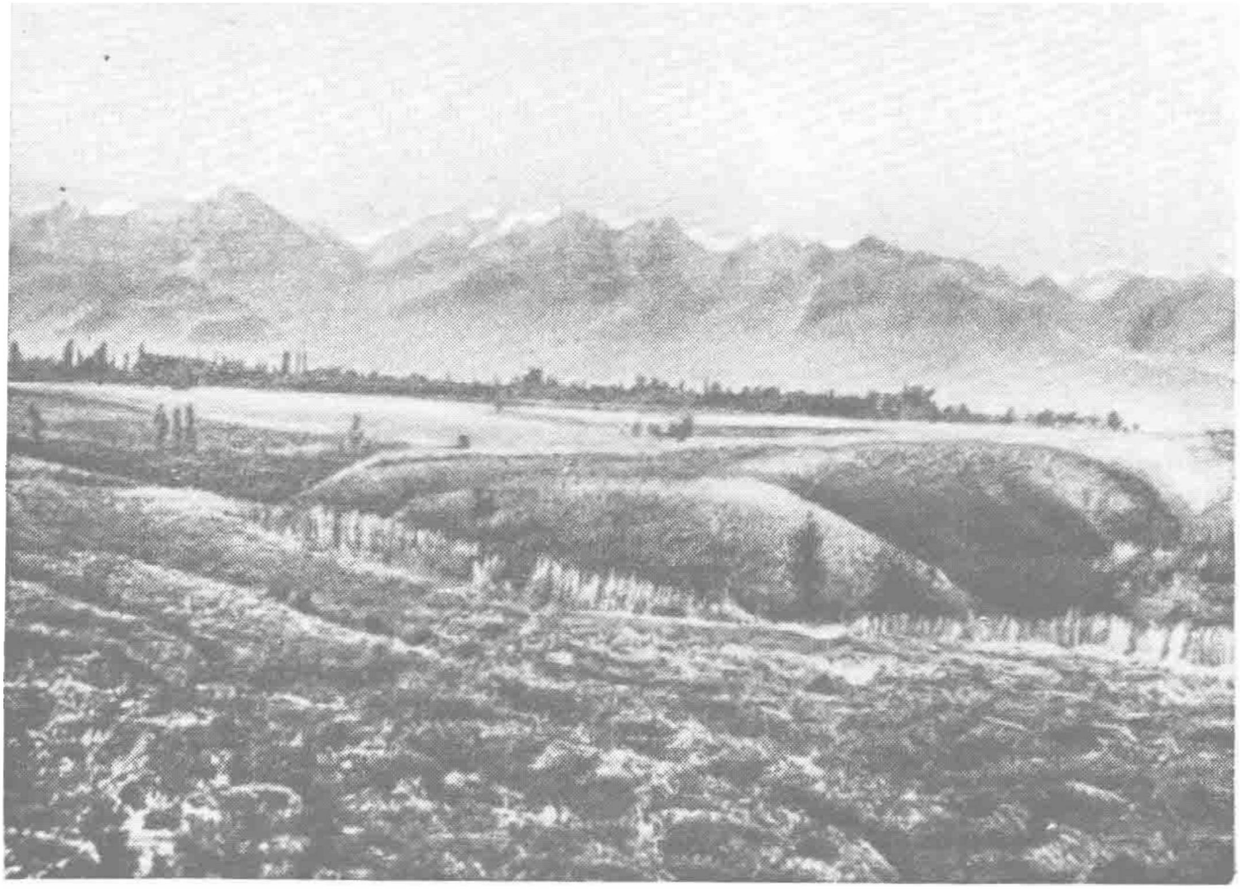
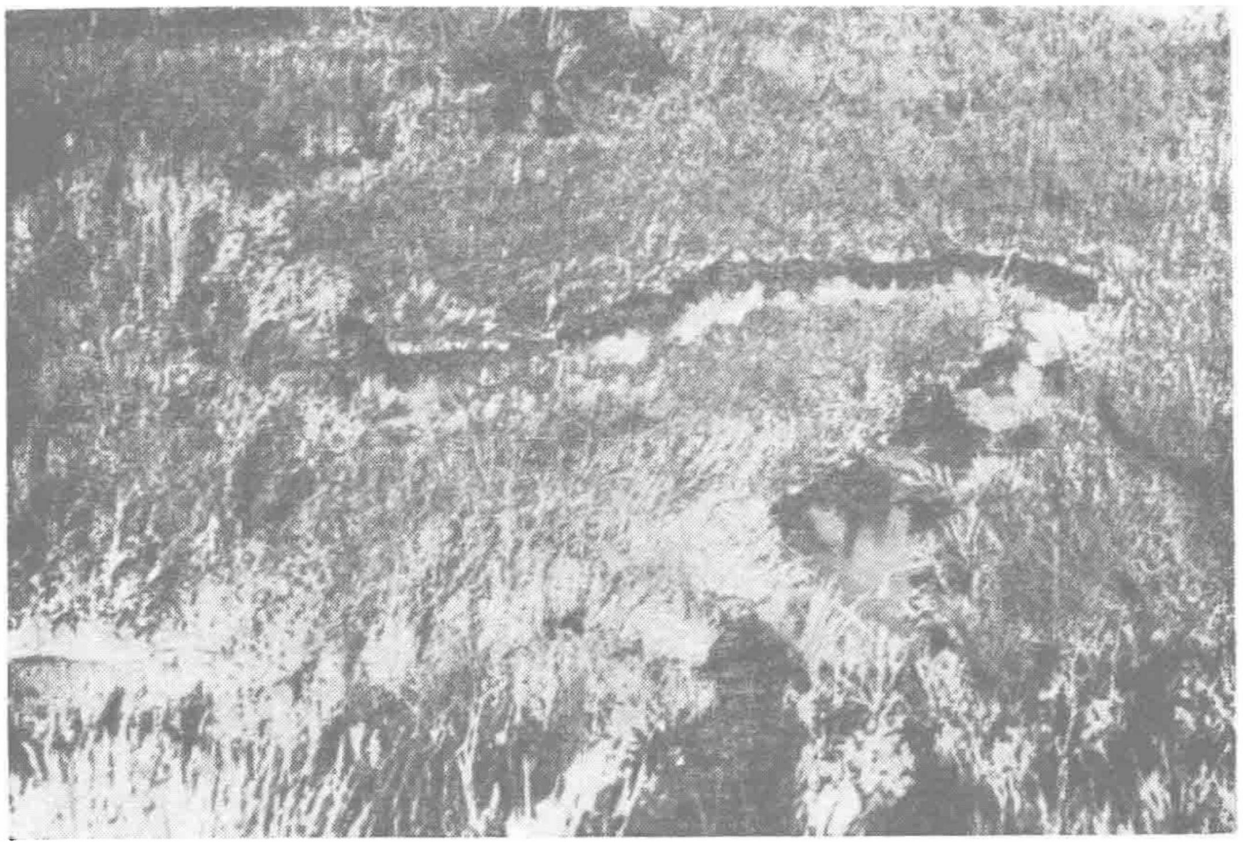


Fig. 51. A ravine, the habitat of water rats in the environs of Alma-Ata. Photo by N. G. Olsufyev.

Fig. 52. The bank of a tributary in the Volga delta with a large population of water rats. Photo by N. D. Mitrofanov.



F i g. 53. The bed of a spring stream, a biotope of water rats. The environs of Alma-Ata. Photo by N. G. Olsufyev.

F i g. 54. Houses in the lower part of the Volga delta during high water. Contact with water rats becomes more frequent. The Astrakhan game preserve. Photo by N. D. Mitrofanov.

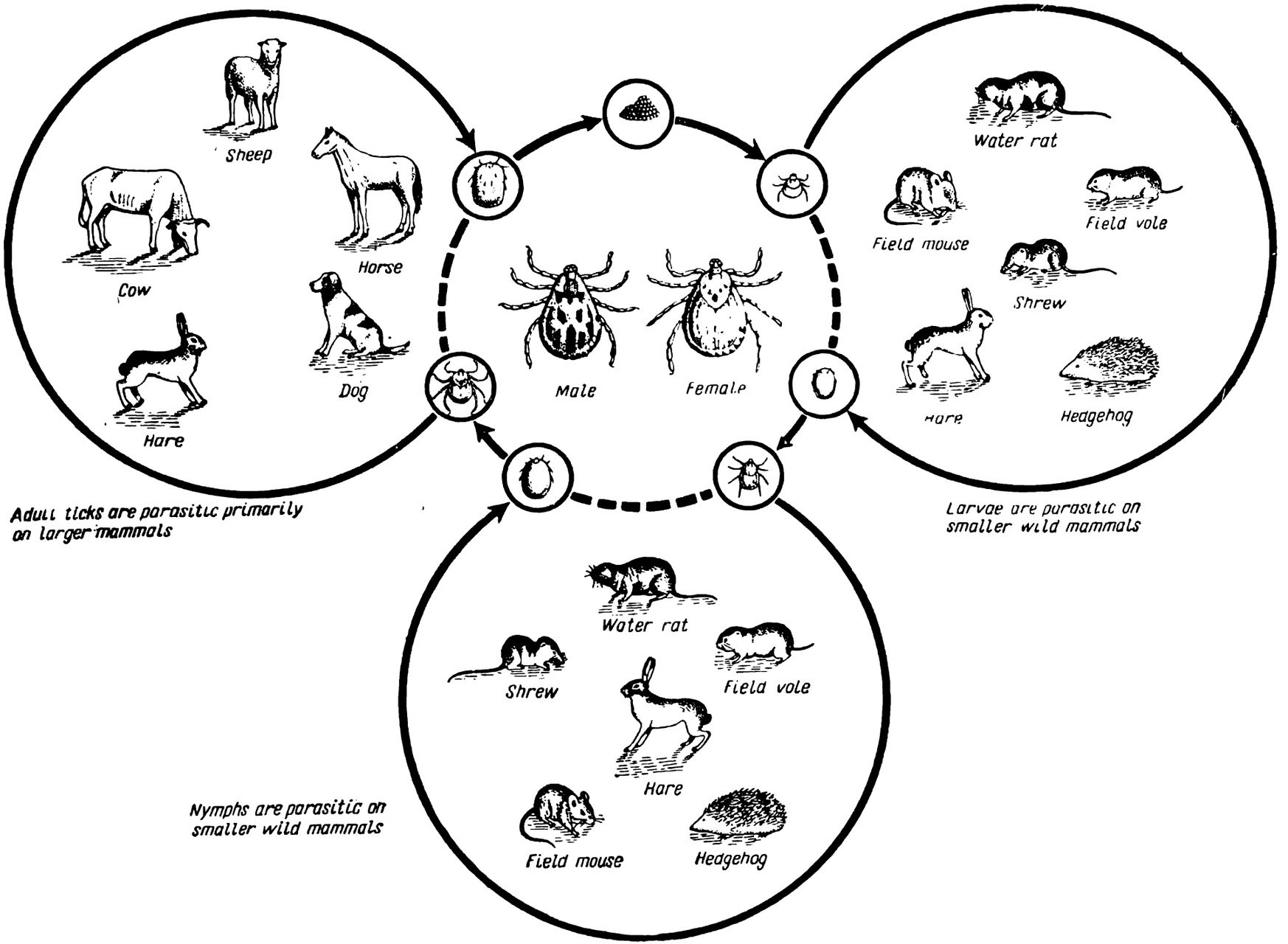



Fig. 55. Donors, vectors, and recipients of *B. tularense*. Drawing by N. G. Olsufyev.

The nymph attaches itself to some mammal, commonly a small animal, and after having its blood meal transforms some time later into a female or a male, which consequently feed for the third time in their life.

Mosquitoes in the larval stage live in water and feed on whatever they can catch in the superficial layer of the water reservoir (minute organisms, bacteria); having turned into nymphs (pupae) they cannot feed at all and after being hatched as female imagoes they become bloodsucking in the majority of species. The females attack man or animals several times and draw their blood.

The differences in the feeding habits of vectors determine, in particular, the type of transmission of infection irrespective of the type of disease-producing agent (virus, bacterium, protozoon, etc.). Therefore, engorged *Ixodes* tick larvae may transmit a pathogenic agent only during their subsequent blood meal, i.e., after transformation into a nymph. The nymphs engorged with infected blood transmit the corresponding pathogenic agent after they have transformed into female imagoes.

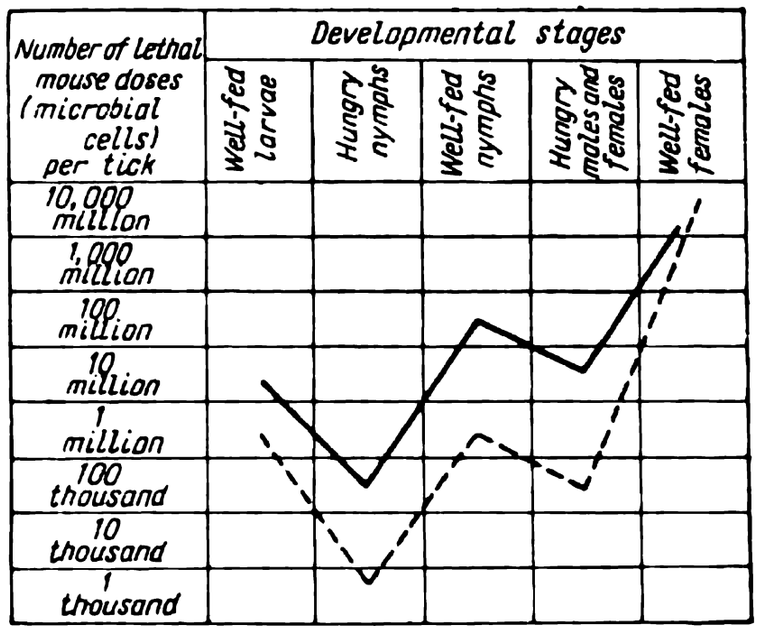
The range of hosts on which ticks prey is wide, therefore, their feeding habits and the sequence of infection transmission are varied, as evidenced by the scheme of transmission of tularemia infection in the process of metamorphosis of the tick vector of the species *Dermacentor pictus*, to whose biological characteristics is added the fact that its larvae and nymphs feed on small animals whereas females feed on larger animals and man (Fig. 55).

A sick human being cannot be a source of infection to be transmitted to a well person by a *Dermacentor* tick, since the latter can draw human blood only once, in the imago stage. The *Dermacentor* larvae and nymphs feed and become infected on an animal donor, whereas larger animals and man acquire the infection from females which have come into being after the molt of infected nymphs *.

If the feeding *Dermacentor* females are the first to acquire infection during their metamorphosis they become a cul-de-sac on the route of tularemia agent circulation in a natural focus, since no transovarial transmission of *B. tularense* by ticks takes place, as held by the majority of authors (*Tularemia*, 1960, pp. 168-169), and an engorged female tick will not feed for a second time.

A cyclic recurrence of its own kind is noted in the state of *B. tularense* multiplying in *Dermacentor pictus* tick vectors which, just as the other *Ixodes* ticks, are true reservoirs of this microbe in nature for a fairly long time which elapses between epizootics. In the sexually mature *D. marginatus* ticks, as evidenced by V. G. Petrov, the tularemia microbe may retain its initial virulence for 7 to 10 days.

* Possible cases of infection of rodents by passive transmission as a result of their eating infected ticks *parasitic* on them are left out of the present discussion.




F i g. 56. The rate of reproduction of *B. tularense* in *Dermacentor pictus* ticks in the course of their metamorphosis. From monograph *Tularemia* (1960) by N. G. Olsufyev and G. P. Rudnev.

Dashed line—series I; continuous line—series II.

In the process of *D. pictus* metamorphosis the reproduction of *B. tularense* in this tick occurs irregularly. While engorged larvae are getting ready for molting into nymphs the number of microbes harboured by them decreases; in engorged nymphs it grows again. When the latter approach the stage of molting into males and females this number decreases again (though to a lesser extent) and then considerably grows in engorged females (Fig. 56).

Other types of tularemia outbreaks are described below.

Gadflies also serve as a vehicle in the spread of tularemia. The transmission of *B. tularense* by them is a purely mechanical process, through a puncture of the skin with a polluted proboscis within two days after the gadfly has acquired infection by biting a sick water rat or rabbit (experiments by N. G. Olsufyev et al.).

It should be emphasized that gadflies naturally infected by *B. tularense* have been found in nature also, in a locality where cases of tularemia occurred among humans. Natural infection with tularemia has been discovered in aphis lions (*Chrysops relictus*) and rainbreeze flies (*Chrysozona pluvialis*).

Gadflies are extremely widespread in Soviet territory—from the tundra to the deserts, from the plains to the Alpine meadows. They are the most numerous in taiga and forest regions, especially those abounding in marshland, while in the south gadflies multiply en masse in the floodlands and shallows of the rivers Volga, Don, Dnieper, Syr-Darya, etc., and on the low shores of the Caspian, the Aral Sea, and lakes.

The extent of harm caused by gadflies in different years, specifically in the northern part of the U.S.S.R., entirely depends on the weather. Their reproduction is favoured by a hot and dry summer; in such years gadflies are especially troublesome, and their bites are keenly distressing to both animals and man. Gadflies have cutting mouth parts with which they puncture the skin and discharge the secretion of their tubular salivary glands into the wound. This secretion has an irritating effect and inhibits blood coagulation. Therefore, the wound from a gadfly bite bleeds continually, while animals harassed by swarms of gadflies, though trying to keep them off as hard as they can, are unable to pasture, let alone perform any agricultural work. Owing to such restless behaviour of animals, part of the gadflies which have not yet had their meal of blood (*Tabanus* draws up to 200 mg of blood) are forced to interrupt their feeding and fly away in search of another animal or human prey. Such "intermittent" feeding may contribute substantially to the transmission of anthrax bacteria, which in effect is a purely mechanical process. N. G. Olsufyev reports that gadflies also bite the carcass of an animal (horse, etc.) immediately after its death from anthrax. At the time of its death the peripheral blood of an animal contains numerous anthrax bacteria and poorly coagulates, as a result of which the mouth parts of gadflies become contaminated with infected blood. It has been found experimentally that anthrax bacilli may survive up to 5 days within fissures between the gadfly mouth parts while those ingested into the stomach may be eliminated with feces during two days. An unengorged gadfly driven away from its prey immediately tries to find and bite another animal or man and puncturing their skin with its mouth parts contaminated with bacteria confers the infection; this occurs in a much shorter time than 5 days.

Gadflies often draw water; even I. A. Porchinsky reported in his time that in a hot weather gadflies land on water and take off again after they have quenched their thirst. Moreover, they may suck wet soil and earth saturated with blood from animals killed by anthrax; in this way also the mouth parts of gadflies can become contaminated with anthrax bacilli. Blood meal is in general indispensable for them since it is from ingested blood that female gadflies draw nutriment for their eggs. A female gadfly lays 400-600 eggs on the average, but there are even more productive species depositing up to 1,000 eggs.

In the southern regions, the influence of the climatic factors on gadflies is more uniform; therefore, their activity there is more or less unvarying year after year. In the northern regions, however, the situation is quite different, since the effects of climatic factors on gadflies are much stronger there. Thus, gadflies begin to fly at an air temperature of at least 15°-16° C and become the most active at 19°-20° C and higher. Gadflies are particularly active on sunny days, with the exception of rainbreeze flies (*Chrysozona*) which

begin to fly at an air temperature below 16° C in a cloudy weather and can fly even when it drizzles. When the wind is high gadflies are less active.

It is only female gadflies that draw blood, while males lick various plant juices, nectar and dew-drops containing sweet secretions of plant lice.

Such vigorous fliers as gadflies, males also, need water for drinking. Even I. A. Porchinsky in his time used this characteristic for their destruction by pouring kerosene into shallow bodies of water thereby turning them into "death pools" for gadflies. Although the water in such pools was covered with a film of kerosene, gadflies landed on it. The kerosene spread over their bodies, obstructed their breathing tubes and was partially taken in with water, as a result of which the gadflies ultimately perished. It is interesting to note here that collecting dead gadflies in such pools I. A. Porchinsky often found such species which were rarely captured by conventioned methods, if at all.

### TULAREMIA OUTBREAKS ASSOCIATED WITH ANIMAL TRAPPING

Tularemia outbreaks associated with animal trapping came on the scene after water rat trapping had been started on a commercial scale in the Soviet Union in 1927.

Added to this was the trapping of muskrat (Fig. 12) imported into the U.S.S.R. and introduced into its fauna. The periods of trapping these fur-bearing rodents vary. Water rats are trapped mostly in spring, when these rodents escaping high water gather in elevated, unflooded places or on shrubs, where they are easily caught. This trapping trade grew to sizeable proportions, the annual total of procured pelts reaching several million for the whole of the U.S.S.R. Tularemia outbreaks associated with this occupation were reported in the early years after the beginning of water rat trapping (1927-1928). Depending on the scale of trapping operations, the disease afflicted not only trappers but also members of their families that helped to strip off and treat the skins.

Diseases associated with the trapping of muskrats were reported since 1937, although less frequently than in the case of water rat trapping, the mechanism of their origination being identical save for a new etiological factor consisting in the use of cooked muskrat meat for food.

In the U.S.S.R, other small fur-bearing animals are also hunted in various regions, such as the sable, squirrel, polecat, ermine, etc., as well as insectivores, such as the shrew, mole, desman, water shrew, etc. But the roles played by these animals in the origination of epizootics and in sustaining natural foci of tularemia are far from being identical. This difference is determined by the regularity with which the above mentioned animals are involved in epizootics,

which is contingent on their specific susceptibility to tularemia infection and on the course taken by the disease in a specific case. It is the latter that determines the rate of human infections during the trapping operations. At the top of the list are the water rat, the muskrat and the hare and among the insectivores—the mole. These animals, in addition to being very susceptible (i.e., easily infected) are highly sensitive to tularemia (i.e., suffer acutely from it). The squirrel, like various species of susliks, as well as the coypu desman, and water shrew, and many other animals, although being susceptible to tularemia (i.e., liable to catch this infection), are nevertheless slightly sensitive to it. The ermine, the polecat, and the fox are slightly susceptible and practically insensitive to tularemia. It follows from this that the significance of commercial animals in relation to the rate of tularemia among professional trappers varies substantially.

### WATER RESERVOIRS, THEIR POLLUTION, AND WATER-BORNE TULAREMIA OUTBREAKS

An important role in the spread of infection is played by the contamination of fresh-water reservoirs ranging in size from pools of brief existence to the largest lakes and inland man-made seas formed in the country's territory and from streams to large rivers by various pathogenic microbes and by the term of the latter's survival in them. This applies almost primarily to tularemia whose water-borne outbreaks are fairly common. In connection with extensive research in tularemia and its control in the U.S.S.R. the relation of its causative agent to water has been studied in detail (Dunayeva, 1959; bibliography indicated herein), the more so as in the U.S.S.R. tularemia infection of man not only through well water but also through polluted water in streams has been observed.

It is interesting to study the mode of such water pollution, which depends on the prevalence of epizootics among water rats, muskrats, desmans, and terrestrial rodents living near water basins where their dead bodies may therefore be found.

In water reservoirs infected by the tularemia microbes the latter may be discovered in the water itself and in the bodies of its vertebrate and invertebrate inhabitants, such as fish, frogs, mollusks, crustacea, river-beetle larvae, etc. Whether these indigenous inhabitants of fresh waters may for their part contribute to sustaining the pollution of water or they serve as a cul-de-sac on the migration route of tularemia microbes harboured by them is a disputable question requiring further study. Even if no reproduction of tularemia microbes occurs within the bodies of such aquatic animals (which are referred to as hydrobionts by certain researchers) the microbes harboured by them nevertheless migrate into water during decomposition of their dead bodies. The significance of this migration, as it may be presumed, depends on the properties of the microbes, the size

of the water reservoir, the time factor, etc. An adequate study has been made on the bacterial contamination of water by the dead bodies of tularemia-affected mammals which are dependent on a water reservoir and live on or near its banks.

This question may be subdivided into two parts: (1) the need to find out the conditions of microbial pollution of the water reservoir itself and (2) determination of what is required for the infection of tularemia-susceptible species of animals with contaminated water as regards the concentration of microbes within it.

These questions were studied experimentally on different species of animals susceptible to tularemia, for example, by T. N. Dunayeva (1959). It has been found in many experiments that tularemia microbes can be detected bacteriologically in a water reservoir containing from 1 to 10 microbial bodies per cu cm of water.

It is important to know the rate of propagation of microbes in the body of a susceptible animal killed by tularemia. It has been determined in numerous studies that one gram of spleen tissue of various species of rodents contains from 10,000 million to one trillion of microbial bodies. One dead body of a water rat, Norwegian lemming, or albino mouse killed by tularemia may infect up to 500,000 litres of water.

If one keeps water rats, field voles, hamsters and other animals in water containing from 100 to 1,000 tularemia microbes per cu cm for a short time under laboratory conditions 47.7 per cent of them will contract the disease. If the microbial concentration is higher—up to 10,000 bodies per cu cm of water, the rate of infection will soar to 90 per cent. At a low concentration of only 10 microbes per cu cm no infection was usually noted.

Infection from polluted water in most of the animals enters through the eyes or respiratory passages, and in certain water rats, golden hamsters and guinea pigs the microbes penetrated through skin lesions and even through an apparently intact skin and invaded their blood.

All of such data should be borne in mind when estimating the tularemia hazards for human beings coming in contact with polluted water.

### AGRICULTURAL OUTBREAKS OF TULAREMIA

It has been established with certainty that unthrashed stacks of grain crops are quite attractive for rodents as their winter dwellings. The common voles account for almost a half of the inhabitants of hay and straw stacks (from observations in a district of the middle zone of the European U.S.S.R.). The extension of tularemia here gives rise to an epizootic among rodents as a result of their feeding on carrion and through polluted food and bedding, especially as the low winter temperatures favour the survival of microbes both

in grain and in straw (Olsufyev, Kucheruk, Dunayeva and Rubina, 1955). Epizootics in hay and straw stacks flare up when natural foci of tularemia exist nearby, from which tularemia microbes are brought to hay and straw stacks.

In winter, straw stacks (Fig. 49), chaff heaps (in the fields) are turned in order to capture rodents, which are dissected so as to determine their biological condition (age, number of embryos in females, etc.) and used for bacteriological studies with a view to forecasting the prospective prevalence of epidemiologically dangerous species of rodents and drawing up the required pest control measures.

In case of a belated thrashing of stacks of various grain crops farm workers are likely to contract tularemia. G. P. Uglovoi (1955) observed the development of various clinical forms of tularemia among non-vaccinated workers. The forms of the disease depended on the specific route by which tularemia microbes had entered the human body from the external environment. Without reference to clinical details, all cases of tularemia may be subdivided into two groups: those involving the air passages and with angina-type symptoms and those affecting the intestine.

The occurrence of one form of tularemia or another depended on the particular crop which was being thrashed. Thus, in thrashing grain crops affections of the air passages prevail in consequence of respiratory infection from inhaled dust. When thrashing peas which are often eaten at work not only by the workers themselves but also by children crowding nearby anginose and intestinal forms of the disease prevail in both.

Contact between animals of one and the same species becomes closer in the years of intensive reproduction of rodents when they infest stacks of grain crops not thrashed in due time and left in the field for winter.

Contact between animals of different species takes place when rodents climb into strange burrows, when a flesh-eating animal attacks its prey and picks up the latter's ectoparasites (e.g., a cat attacked by mouse fleas); in places heavily infested by mice they may come into direct contact with man (e.g., when mice get into the beds of sleeping people at night or when people throw mice killed by a plague epizootic out of their house).

Under specific conditions epizootics of rodents may be also combined. This occurs in winter with the common vole infesting stacks of straw. N. G. Olsufyev and O. S. Yemelyanova (1954) observed a combined epizootic of tularemia, listerellosis and streptococcic infection among common voles, and also detected a listerellosis infection not only in rodents but also in insectivores and *Ixodes* ticks. The authors report that *Listeriae* are easier recovered from rotting dead bodies since this microorganism multiplies in dead organic matter; in cases of advanced decomposition of an animal body one is advised to take the marrow of tubular bones for cultivation.

## THE TYPES AND DISTRIBUTION OF NATURAL FOCI OF TULAREMIA

The largest number of natural foci of tularemia have been discovered in the European part of the U.S.S.R. and in Western Siberia; a detailed survey of the eastern part of the Russian Federation will possibly reveal more foci of this disease.

### TYPES OF NATURAL FOCI OF TULAREMIA

It is evident on the first gaze at the distribution of natural foci of tularemia in the U.S.S.R. that they are confined to different landscapes, which has made it necessary to specify their types associated with a particular part of a landscape zone.

Such classification of disease foci is not only of theoretical interest but is necessary for drawing up and implementing a complex of prophylactic measures for tularemia control differentiated in relation to the nature of specific foci, as well as for prognostication with regard to prospective epidemic and epizootic hazards.

The differentiation of natural foci of diseases involves the determination of their structure and basic elements on which the state of a particular focus depends.

The types of tularemia foci make the subject of a number of papers and even of a special book (Maksimov, 1960). The types of natural foci are classified by different authors on the basis of different criteria. There is no uniformity in this respect. Being unable to discuss here the various views on the subject we shall dwell on a more well-grounded classification of natural foci of tularemia based on the aggregate of specific features of biotopes with which its natural foci in the U.S.S.R. are linked territorially.

In the opinion of N. G. Olsufyev and T. N. Dunayeva (1960) the subdivision of natural foci of tularemia into at least six basic types is the most reasonable. These are as follows: (1) floodland and marshland foci: (2) meadow and crop field foci (Fig. 57); (3) forest foci; (4) steppe (ravine) foci; (5) foot-hill and stream foci (aquatic foci after S. P. Karpov; Fig. 58); and (6) tugai and desert foci (after G. A. Kondrashkin; 1957).

It is clear that such types of foci can be encountered in different landscape zones. The above classification may be made more elaborate both by the discovery of new types of foci in subsequent surveys and by fragmentation of the known types of foci into subordinate types according to the specific features of a particular focus *structure*. The suggested separation of smaller foci, termed microfoci of tularemia by the above-mentioned authors, is conventional, since this in fact blurs the demarcation of these foci generally diffuse in one landscape zone or another. The author's suggestion to specify *elementary foci* is based on the character of their physical boundaries. These are,

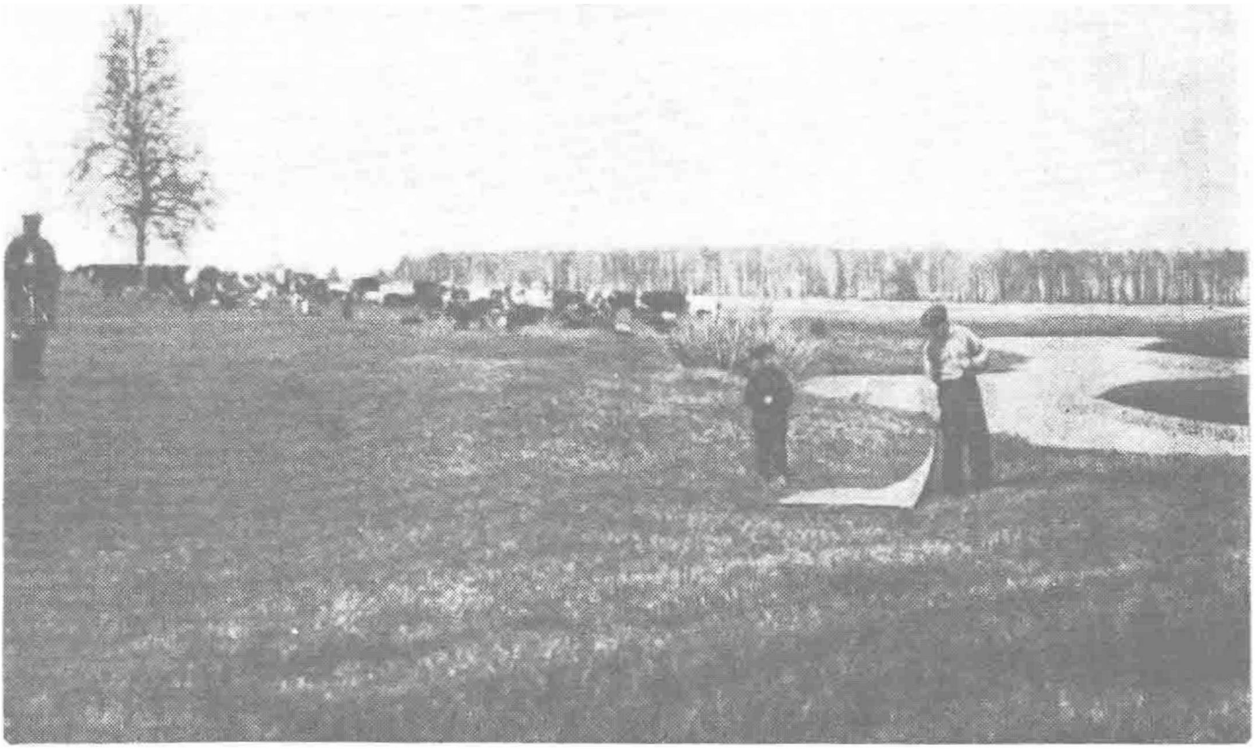


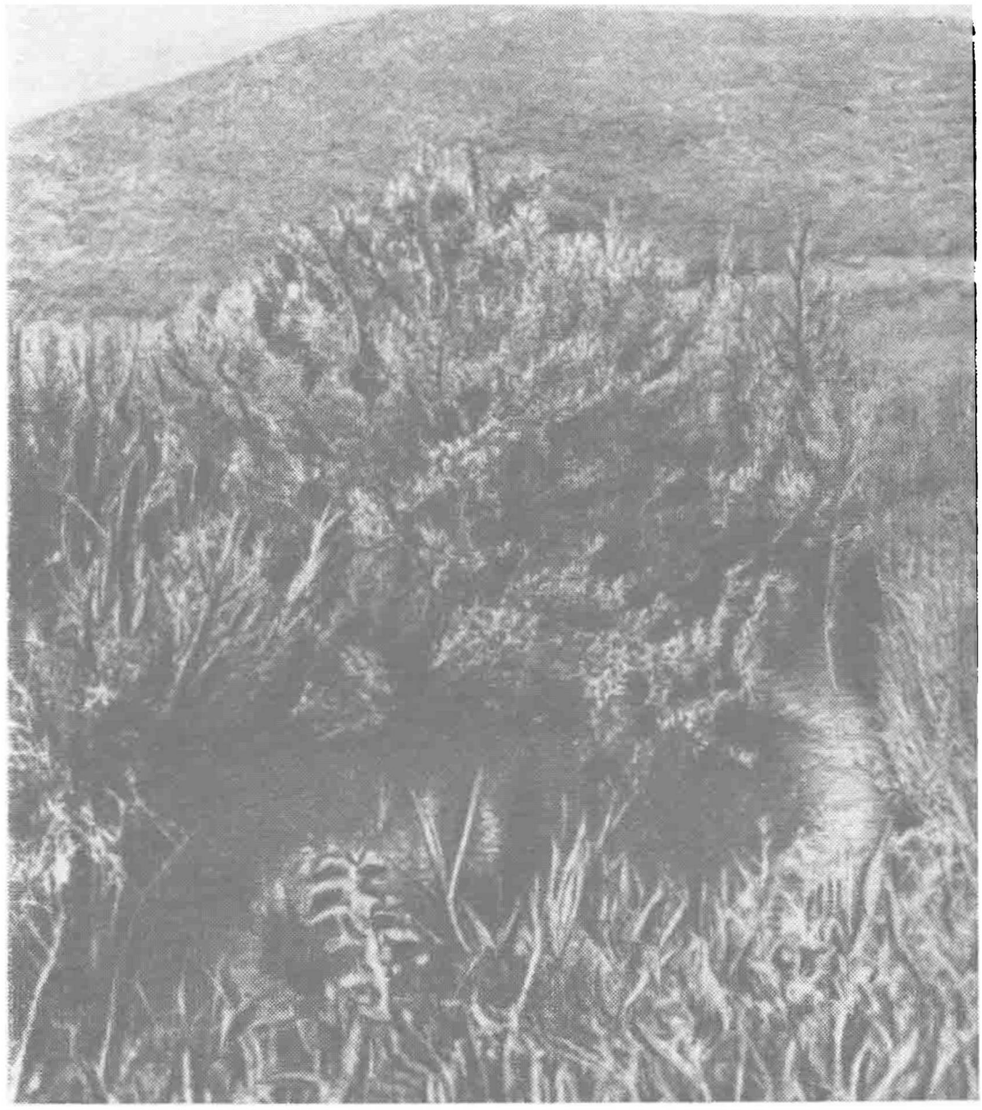
Fig. 57. The meadow-field type of natural focus of tularemia. Photo by N. G. Olsufyev.

for example, such "limited" elementary foci as burrows, caves, animals' and birds' nests, which are opposed to the diffuse-type natural foci lacking any definite outward boundaries, such as the litter in a forest of cedars and broad-leaved trees inhabited by ticks—vectors of tick-borne encephalitis. For the term "elementary focus" to be supplanted by the term "microfocus" (mesofoci are also known!) one should establish a certain qualitative index.

The burrow of the harvest mouse and the porcupine's lair reaching 10 to 12 metres in depth represent elementary foci to which the general term "microfocus" is hardly applicable logically. A colony of gerbils can with little reason be called a microfocus but it may be attributed to the type of the *combined*, or multiple, elementary foci, disregarding the fact that dialectically quantity undergoes transition to a new quality, since the latter is unrelated to the basic definition of the elementary natural focus of a disease.

*Meadow and field* foci are characteristic of the middle belt of the European part of the U.S.S.R. and are also encountered in the forest and northern forest-steppe zones. The leading members of the biocoenoses of these foci are field voles as the principal source of tularemia infection and *Dermacentor pictus* tick vectors which in the northwest give place to *Ixodes ricinus* ticks.

When forests are cut down meadow and field foci extend to the former forest area and, once the cleared land has been planted to



F i g. 58. A willow bush near which a water rat killed by tularemia was found. Photo by N. G. Olsufyev.

crops, field voles find new biotopes in the stacks of straw. Handling these stacks farm workers contract tularemia by inhalation.

*Steppe* or *ravine* foci of tularemia are confined to ravines overgrown with brush where concentration of small mammals and ticks is favoured by increased humidity. For the variety of leading biocoenosis species such foci are polyhostal (field voles, hamsters, hares, mice, and other rodents) and polyvector (ticks *Dermacentor marginatus*, less frequently *Rhipicephalus rossicus*, *Ixodes laguri*, and other *Ixodes* ticks, and possibly gamasid ticks of the family *Dermanyssidae*). Epizootics also spread among house mice which contribute to household, agricultural and well-water-borne tularemia outbreaks. Steppe foci of tularemia are common to the southern regions of the European part of the U.S.S.R.

In the broad-leaved forests and in the southern part of the mixed woodlands *the forest type* of natural foci of tularemia is prevalent. The leading members of biocoenoses here are bank voles (*Clethrionomys glareolus*), forest mice, hares and probably other animals. The vectors are the forest tick *Ixodes ricinus* and the burrow tick *I. trianguliceps*. The infection is most commonly acquired by people hunting hares and using them for food (particularly in Western Europe, e. g., in Czechoslovakia).

As distinct from the above-discussed foci the *flood-* and *marshland* foci are confined to elevated areas of river-flooded plains and river deltas, inaccessible to high water. The largest rivers of the U.S.S.R. follow a meridional course across latitudinal landscape belts; this alone is enough to account for the intrazonal character of such tularemia foci extending both to the bogged-up river banks and lake shores. The principal vehicle in the spread of tularemia is the water rat, other very susceptible and highly sensitive animals being also involved in various places. Consequently, these foci, too, may become polyhostal as well as polyvector, harbouring ticks, the vectors and reservoirs of *B. tularense*, which in different places belong to the genera *Dermacentor*, *Ixodes* and *Rhipicephalus*, and possibly to the gamasid species of the family *Dermanyssidae*.

*Foot-hill* and *stream* foci are characteristic of the foot-hills of Siberia, the Caucasus, Kirghizia, etc. Such foci are sustained, in particular, by the water rat, the common vole and other aquatic neighbours of the water rat also being involved in epizootics (animals of the second group with reference to tularemia incidence: see p. 72). The typical vector is the tick *Ixodes apronophorus* as well as other co-inhabitants of the species *Dermacentor* and at places *Haemaphysalis*. In localities characterized by the type of the tularemia focus in question its water-borne outbreaks are common in summer, inasmuch as stream water and bottom silt become polluted, and consequently infected, by tularemia-affected water rats.

*The tugai type* of foci is characteristic of Central Asian rivers whose banks are overgrown with tugai—small trees and shrubs. Some examples are the middle reaches of the river Chu in Kirghizia, the lower reaches of the rivers Ili, Amu-Darya and the delta of the river Syr-Darya. Such foci are common in deserts. Here tularemia has been found in sand hares (Lepus tolai), gerbils, muskrats and other animals, while the causative agent has been recovered from the tick *Rhipicephalus pumilio*.

## THE DISTRIBUTION OF TULAREMIA ACCORDING TO LANDSCAPE ZONES

Such a variety of types of tularemia foci in nature is aggravated by the fact that this disease is encountered in all flat landscape zones of the U.S.S.R., such as the tundra, forests, forest-steppes, steppe

and deserts, and at places extends to the mountains. Tularemia is the most common in the forest-steppe and steppe, partly in the broad-leaved forests, floodlands and deltas of rivers, on lake shores and marshland. In the territories of the above-mentioned landscapes natural foci of tularemia have a mosaic distribution, being confined to definite stations and biotopes [Olsufyev, 1959 (1960)]. This description will be limited to the essentially motley distribution of tularemia and need not be repeated in the subsequent discussion of the overall incidence of diseases with natural foci common to specific landscapes in the U.S.S.R.

Tularemia has been found in several scores of species of wild animals. It has also been found to be transmitted by a host of species of bloodsucking vectors (animal lice, fleas, mosquitoes, gadflies, *Ixodes* ticks, etc.). Consequently, this disease should naturally be listed among transmissible diseases. The major source of the infection as regards the initial cause of human morbidity is the water rat (Figs. 46, 47), of late called the water vole (Arvicola terrestris). It inhabits a number of rivers and digs burrows with an underwater entrance. Its name of "water rat" has become common in the vast literature on tularemia, and will therefore be used here, bearing in mind, however, that systematically it belongs to the field voles.

The water rat is hunted for its fur. Tularemia-affected rats may also be trapped and transmit the infection to the trapper. If a rat dies from tularemia in water, the latter becomes infective and may transmit the disease to humans drinking it or angling standing for hours in the water near the shore or having some other form of contact with such water. Moreover, tularemia may be contracted in dry surroundings also. It is current in particular among various rodents living in the fields. A sick animal eliminates tularemia bacteria on mowed grass or grain crops. When handling them during farm work humans may contract tularemia by inhaling the infective dust.

Whatever the variety of the routes by which the *B. tularense* is transmitted to man the basic factor is the sustenance of its natural foci by *Ixodes* ticks which transfer this bacterium from sick to healthy animals, for instance, on a pasture. On the eve of the Second World War (1941), N. G. Olsufyev found natural infection with *B. tularense* in *Ixodes* ticks captured on a riverside pasture in one of the central districts of the European part of the Russian Federation. After the end of the war, 5 years after the above discovery, N. G. Olsufyev examined *Ixodes* ticks on the same pasture (Fig. 57) and again found tularemia-infected individuals among them. Five years is not, of course, the time-limit for a natural focus of tularemia, but is enough to illustrate the principal role played by *Ixodes* ticks as harbourers of *B. tularense* in sustaining the infection on the pasture which serves, therefore, as a natural focus of tularemia.

## TOXOPLASMOSIS

Toxoplasmosis is a disease with natural foci, which is widespread, particularly in a latent form, among humans, mammals, and birds. It is caused by *Toxoplasma gondii* (Figs. 59, 60). The source of infection with *T. gondii* is lodged in the synanthropic and some other wild mammals and birds; a newborn may acquire toxoplasmosis from its mother as a congenital infection. This disease is a typical zooanthroponosis.

The range of synanthropic animals and birds from which toxoplasmosis can be acquired by man is wide enough, comprising dogs, cats, pigs, sheep, goats, neat cattle, horses, rabbits, rats, mice, pigeons, hens, etc. Among wild animals and birds, hares, squirrels, susliks, moles, black grouse, partridges, etc., may have a similar significance. In most wild animals toxoplasmosis runs a latent course.

Toxoplasmas are discharged into the external environment by heavily infected and apparently sick animals with their urine, feces, saliva, milk, nasopharyngeal and bronchial mucus.

The infection takes place by direct contact, per os or through an injury.

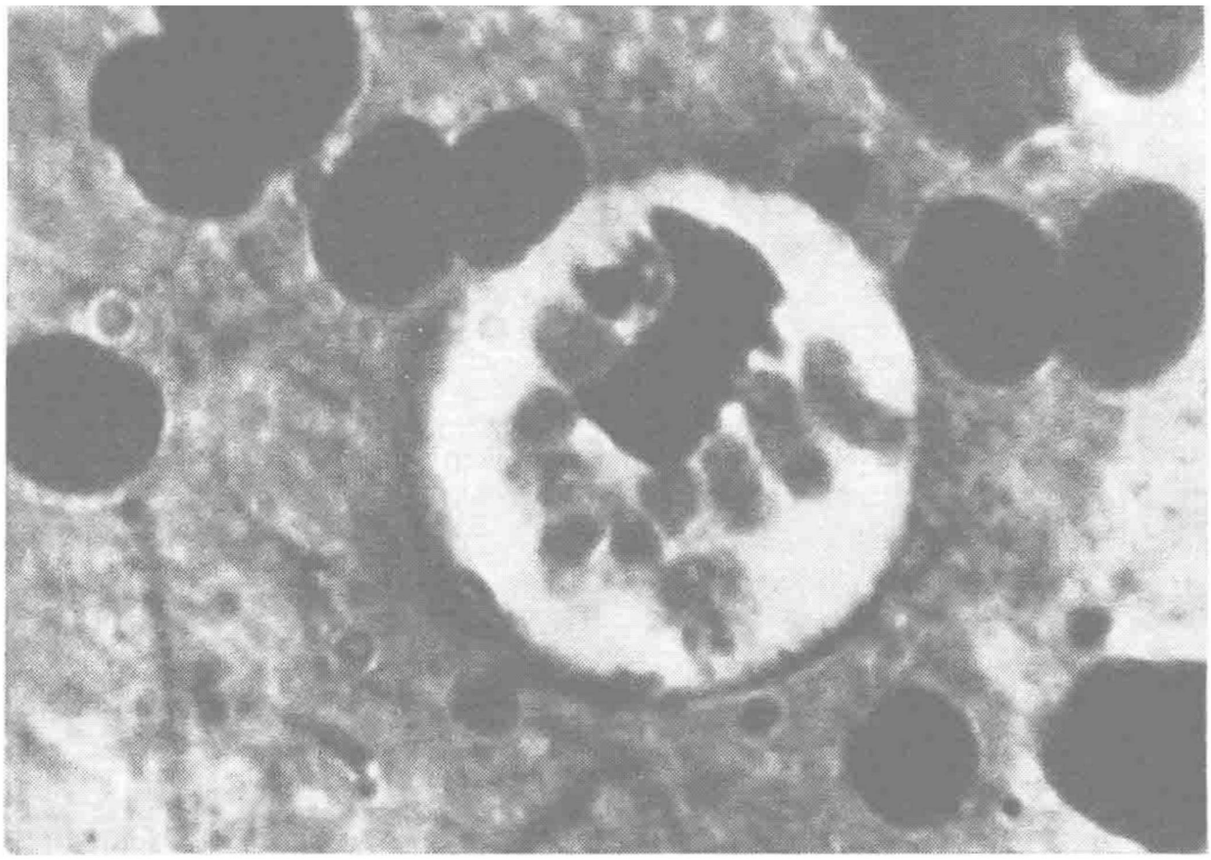
The route of transmission of toxoplasmosis to humans is as follows: from warm-blooded wild animals to synanthropic animals and from the latter to man.

Infection with toxoplasmosis takes place: (1) in direct contact between a sick and a healthy animal of the same or another species (during copulation of domestic and wild rabbits; in overcrowded hencoops: when a healthy beast is fought back and wounded by its prey affected by toxoplasmosis); (2) by an indirect route when eating vegetable food gnawed at or contaminated with feces by an infected animal; (3) as a result of animals cleaning themselves by licking their legs soiled with feces and urine of infected animals, and (4) when animals eat ticks or other ectoparasites infected with toxoplasmas as a result of drawing blood from infected mammals and birds.

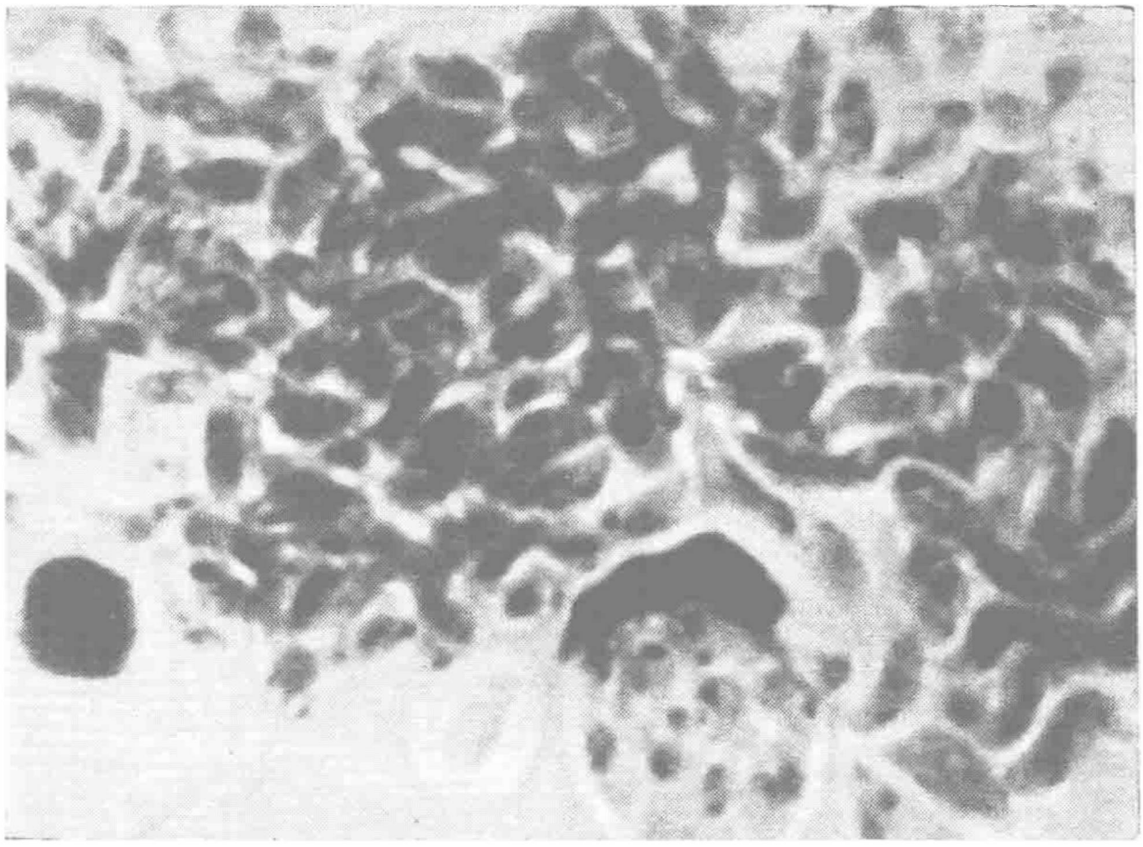
Toxoplasmosis is with good reason attributed to diseases with natural foci, and is transmitted to man by various routes; a pregnant woman with a latent form of toxoplasmosis being likely to infect the fetus and give birth to a monster, or a child with hydrocephalus or an eye disease.

The results of infection with toxoplasmosis, i.e., the course of the disease in man, just as in animals inhabiting its natural foci, depend on a number of circumstances.

O. Iroveč has summed them up as follows: of prime importance are the infective properties of a particular toxoplasma strain, which are found out by experimental infections of laboratory animals. Some strains of toxoplasma fail to cause the disease at all (i.e., they are avirulent), but once they have been passed through the



F i g. 59. *Toxoplasma gondii* inside a mouse liver cell (smear). Microphotograph of D. N. Zasukhin's preparation. High magnification.



F i g. 60. *Toxoplasma gondii*. Massive accumulation in the peritoneal exudate of a mouse (smear). Microphotograph of D. N. Zasukhin's preparation. High magnification.

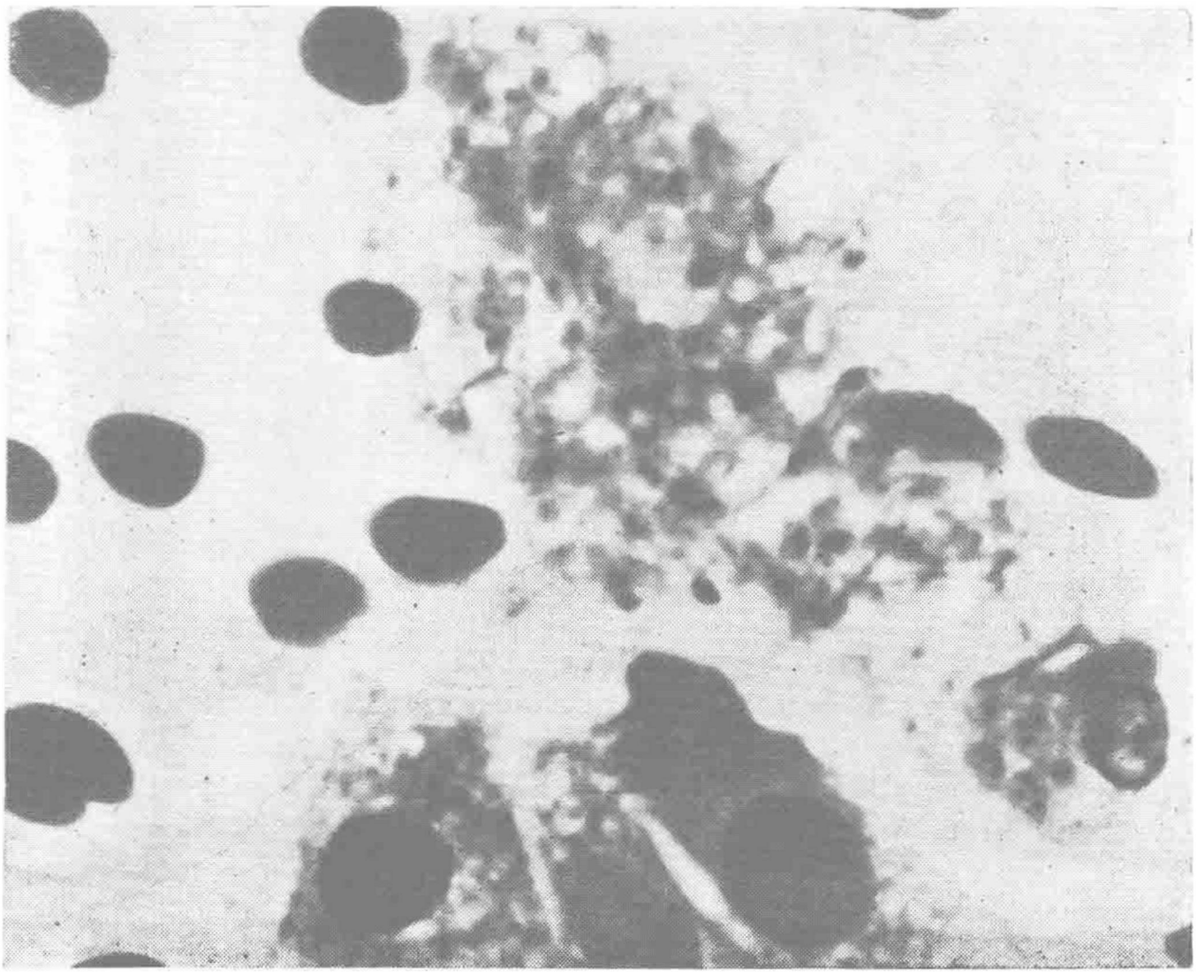
animal body their virulence grows and they become capable of killing infected mice to which other strains remain as harmless as before. Toxoplasmosis foci in nature are sustained by a continuous passive migration of toxoplasma bodies from one animal to another animal of the same or another species. It is possible that toxoplasma bodies do not remain indifferent to such a circulation; evidence of this is the following observation. In Britain, in 1955, toxoplasma bodies failing to cause disease in mice were recovered from 5.7 per cent of examined domestic rabbits; following their inoculation (for the purpose of passage) to South African rats (*Rattus natalensis*) the passaged toxoplasma bodies became sufficiently virulent. In nature, such a migration of toxoplasma bodies from one animal species to another, and especially to a genus, may be quite varied, depending on the multiplicity of species representing members of the biocoenosis of a given focus and on the character of their relationships (biocoenotic associations). It can be presumed that the virulence of toxoplasma may grow in one case and lessen in another; this should be verified by a thorough investigation and experiments on animals belonging precisely to those species and genera which determine the composition of a given biocoenosis. All this refers directly to toxoplasma organisms as the causative agents of toxoplasmosis. It should be borne in mind, at the same time, that virulence is not an absolute property of the microbe itself but is the result of interaction between the microbe, the body of the host of a particular species, and the members of the parasitocoenosis inhabiting it under environmental circumstances favouring infection and disease.

The course of the disease depends not only on the species of the susceptible animal, but also on the age of the recipient (provided the virulence of tested toxoplasma bodies is equal). For example, in young mice, guinea pigs, and hamsters toxoplasmosis often takes an acute course and proves fatal, whereas in adult albino rats it runs a latent course.

In adult humans, toxoplasmosis rarely takes an acute course, whereas its latent form is one of the most widespread diseases, women with latent toxoplasmosis often giving birth to monsters and children lacking vitality as a result of contracting this disease at birth (congenital toxoplasmosis).

The character of the incipient disease depends also on the number of toxoplasma organisms which have entered the body; if they are few the disease takes a latent course, and if they are many (and of one and the same strain) the disease produces characteristic symptoms and often becomes generalized.

The course of the disease also depends on which of the organs of the sufferer is invaded by toxoplasma bodies. If these parasites concentrate in the muscle tissue the disease gives no clinical signs; when they keep to the vascular tunic of the eye it becomes inflamed, which is known as chorioretinitis.



F i g. 61. *Pneumocystis carinii.* Lung smear. Microphotograph by Prof. Iroveč of Prague. High-degree magnification.

It is quite possible that man contracts toxoplasmosis from such domestic animals as rabbits, cats, and dogs. Toxoplasmas probably enter the human body most commonly with inhaled air or through the skin, less frequently through the ocular conjunctiva and even when eating half-boiled or half-roasted meat of neat and small cattle and pork and drinking raw milk from animals with a latent toxoplasmosis infection. Latent toxoplasmosis is a fairly common disease in man. For example, in Czechoslovakia the skin test proved positive for toxoplasmosis at the age of 3 to 6 years and 51 to 70 years in 6.3 per cent and 0.4 per cent of the total number of examined cases respectively (Iroveč, 1961).

During the past few years, toxoplasmosis has been attracting interest in the U.S.S.R. as well. Its study is carried on successfully, and two national conferences on toxoplasmosis attended by clinicians, microbiologists and parasitologists have already been held in Moscow at the Institute of Epidemiology and Microbiology under the U.S.S.R. Academy of Medical Sciences.

Another pressing need is the study of pneumocystosis and its causative agent, *Pneumocystis carinii* (Fig. 61). Although both of these diseases are regarded as "new" for the U.S.S.R. they are not

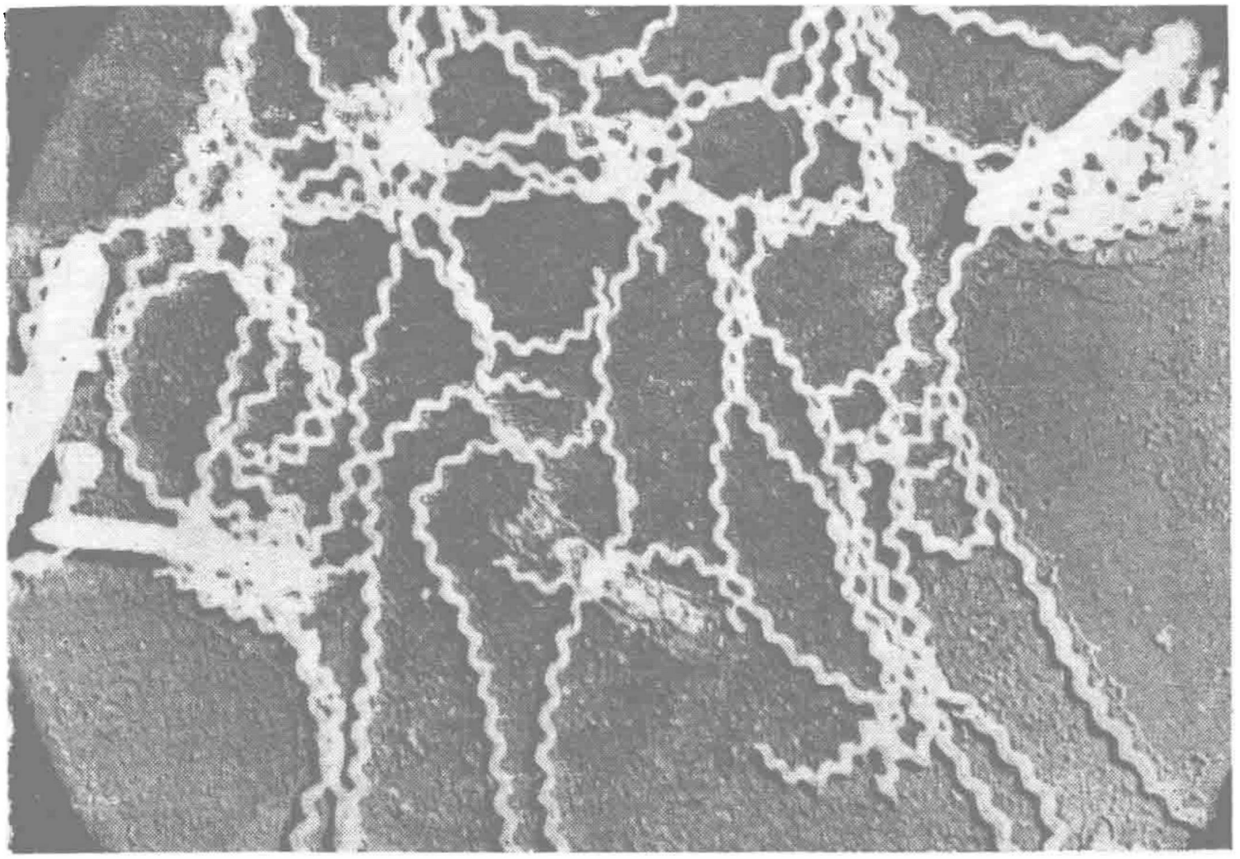


Fig. 62. *Leptospira autumnalis.* Electron microphotograph from the Institute of Hygiene at Lublin (Prof. Parnas).

in effect such, but have simply become discoverable by new diagnostic techniques. This is particularly characteristic of toxoplasmosis. It is quite probable that pneumocystosis, once a vigorous search for it has been started, will not prove a disease of exceptionally rare occurrence either.

The "novelty" of a disease and its prevalence are clearly illustrated by the example of leptospirosis, which will be discussed below.

## LEPTOSPIROSIS, ITS "AGE" AND ROUTES OF PROPAGATION

Leptospirosis which is being extensively studied now is also a relatively new disease caused by *Leptospira organisms* (Fig. 62). It became an object for study at different times in different countries. In Bulgaria, for example, medical men have gained a more or less complete idea of leptospirosis only during the past 10-12 years. This disease is also vigorously studied in Czechoslovakia, Poland, and Italy.

In Bulgaria, more than 200 strains of leptospirae were recovered both from sick humans and from farm and wild animals (a total of over 20,000 farm, about 500 domestic, and about 3,000 wild animals, mostly rodents, have been examined). For their antigenic properties the recovered leptospirae were found to fall into eight types, which

at first were given local names and then included into the general classification (Mitov, Yankov, Ivanov, 1961).

The most important factors in sustaining leptospirosis foci in the rice fields of Southern Bulgaria are such wild animals as the water rat, the harvest mouse, and the common vole. Moreover, *Leptospira bataviae* has been recovered from gray rats, hedgehogs, etc.

Examination of farm animals has revealed leptospirosis in slightly over a half of all pigs, while in leptospirosis foci the proportion of infected pigs grows to 65-80 per cent and the disease has been found in 27 per cent of the cows. Farm animals are most commonly found to harbour *L. pomona*.

Men are more liable to infection than women (in proportions of 4 : 1 to 10 : 1), owing to the former working in localities with natural foci of leptospirosis. Therefore, the disease is the most widespread among peasants (94.3 per cent), whereas town residents contract it but rarely (5.7 per cent).

Two age groups have been noted for the maximum incidence of the disease: children from 8 to 14 years of age (frequently bathing in various water reservoirs) and adults 21 to 40 years of age actively engaged in field work.

Leptospirosis has been discovered in all regions of Bulgaria. But its highest rate and greatest variety have been recorded in the Plovdiv district where the air temperature is comparatively high in summer and autumn, and water is plentiful (particularly in fish-breeding areas).

In one of Kazakhstan's regions, almost 80.3 per cent of all cases of non-icteric leptospirosis were children and juveniles under 20 years of age on account of their more frequent bathing (non-icteric leptospirosis is otherwise known as water-borne fever).

The incidence of leptospirosis should be estimated from the "professional" and from the lay point of view, for which it is necessary to investigate the characteristics of its every outbreak. For instance, in one quarry the rate of leptospirosis among workers was as high as 36 per cent of the total morbidity rate. The reason was water supply to the workers' dwellings from a river polluted by lepto spirae.

A high rate of leptospirosis among pig-tenders on a pig-breeding farm, which grew to the point of an outbreak, was found to be due to their permanent contact with pigs looking quite healthy yet identified by laboratory tests as asymptomatic leptospirae carriers (Leibenzon, 1961).

A high leptospirosis incidence was also noted in people who had bathed in such a large river as the Irtysh, though usually bathers contract leptospirosis in small ponds or pools formed by river dams. The reason for this seeming discrepancy was the existence of a pig-breeding summer farm on the bank of the Irtysh with a large number of swine per unit of riverside length. It is perfectly obvious that

the river in that place was naturally contaminated with *Leptospira* organisms eliminated by pigs in tremendous numbers over a comparatively short stretch of the river bank. The personnel tending pigs and neat cattle bathed here, which was the cause of an outbreak of water-borne fever among them also. The swine and cattle themselves could have been infected from such animals, reservoirs of non-icteric leptospirosis, as the common vole (Microtus arvalis), the long-tailed suslik (Citellus undulatus) and the field mouse (Apodemus agrarius). Consequently, neat cattle and pigs were recipients of infection from nature and then transmitted it to man through permanent contact and through water polluted by them (Leibenzon, 1961).

The pathogenic leptospirae themselves can survive and multiply in water for as long as 1,318 days (observation time); individual groups (strains) of leptospira at the same time retain their virulence, but still a prolonged presence of leptospirae in water gradually reduces their pathogenicity (Shutyayev, 1961).

*Leptospira grippotyphosa* was recovered from a number of rodent species, carnivorous and insectivorous, captured in their natural habitats, in localities differing in climate and geographical position.

Infections from drinking infected water or eating food contaminated by leptospira-carrying animals occur more seldom than those due to contact with water; infections by direct contact are even less frequent.

According to evidence obtained at V. V. Ananyin's laboratory, pathogenic leptospirae can survive in river, pond and lake water from 5 to 10 days with pH of water samples fluctuating from 7.5 to 0.25, and in swamp water for from 3 to 5 days with pH of water ranging from 6.7 to 7.0. It is believed in general that leptospirae fail to survive long in water with low pH indices (below 6.0-6.5); in water with an increased salt content (seas, salt-water lakes, sphagnum bogs, etc.) they perish early, therefore such water presents no epidemiological hazard.

Cases of leptospirosis also occur in winter (Denmark, the G.D.R., the F.R.G., the U.S.S.R.) but they are of alimentary origin, i.e., result from ingestion of food contaminated with excrements from leptospira-carrying rodents.

Leptospirosis is prevalent in almost every country of the world. It shows high incidence in Japan and Indonesia, and is frequent in Australia and the U.S.A., where it causes greater damage to agriculture than does brucellosis.

In the U.S.S.R. and other countries, non-icteric leptospirosis in peacetime occurs more frequently than Vasilyev-Weil's disease. In wartime, however, cases of the latter disease prevail as a result of the inevitable worsening of the standards of living and increased chances of contact (direct and indirect) between humans and rats, as was the case during the siege of Leningrad (1941-1944).

Fig. 63. *Leptospira icterohaemorrhagiae*. Electron microphotograph from the Institute of Hygiene at Lublin (Prof. Parnas).

**POSSIBILITY OF LEPTOSPIRA TRANSMISSION**

There is serious reason to regard leptospirosis as a transmissible disease under certain circumstances. Thus, according to evidence by I.Z. Soloshenko, *Leptospira icterohaemorrhagiae* (Fig. 63) survives in *Ornithodoros bacoti* ticks for 25 days, in *Hyalomma asiaticum* for the same period, and in *Rhipicephalus rossicus* for only 3 days.

*Leptospira pomona* in *Ornithodoros turicata* survived for 225 days (Burgdorfer, 1956) and *L. icterohaemorrhagiae* in *O. moubata* ticks for 39 days (Schlossberger u. Langbein, 1952). True, the presence, however long, of a pathogenic agent in ticks is not in itself proof that such ticks are vectors of this infection, yet the facts given above indicate the course for experimental studies of this problem.

The literature presents new evidence suggesting the existence of other forms of leptospiral transmission and infection of animals with leptospirosis. Firstly, data have been obtained on the natural infective state of *Ornithodoros tartakovskyi* (Blagodarny, 1961). Secondly, Burgdorfer (1959) published a second paper on the possible role of *Ixodes* ticks as leptospirae vectors. He fed sexually mature *Dermacentor andersoni* and *Amblyomma maculatum* ticks hatched in the laboratory on a strong suspension of *Leptospira pomona* recovered from pigs in Illinois (U.S.A.) in 1953. Some of the female and male ticks subsequently transmitted *L. pomona* to newly-weaned guinea pigs. Leptospirae penetrated through the wall of the tick's

alimentary canal and invaded the salivary glands, the nerve ganglion, the genital system, but were not found in the developed ovum follicles. Attempts to infect hamsters by their exposure to infective nymphs, females and males of both tick species, were unsuccessful. In general, infection with *L. pomona* takes a much less intensive course in pigs and other domestic animals than it does in hamsters (and Burgdorfer thinks it improbable for *Dermacentor andersoni* and *Amblyomma maculatum* to transmit *L. pomona* from domestic animals).

As far back as 1954, in the desert regions of Kazakhstan, T. A. Krepkogorskaya (1954) recovered the causal agent of leptospirosis (water-borne fever) from the large gerbil (*Rhombomys opimus*), which later was repeated more than once. But the large gerbil, a typical desert inhabitant, does not depend on water. In order to discover some other routes of leptospirae circulation in the desert areas, many authors attempted to find natural infection with leptospirae in *Hyalomma* ticks of various species captured on neat cattle kept on a desert farm visited by leptospirosis. For the same purpose, *Boophilus calcaratus*, *Rhipicephalus bursa* and *Ixodes ricinus* ticks captured on leptospirosis-afflicted animals were studied, as well as a large number of gamasid ticks from rodents inhabiting an endemic focus of leptospirosis, and all of them yielded negative results. Identical results were also obtained in examination of gamasid ticks and fleas captured on rodents from which leptospirae had been recovered.

T. A. Krepkogorskaya and M. M. Rementsova (1957) had better luck in their investigations, since in 1955 they managed to recover pathogenic leptospirae from *Dermacentor marginatus* ticks captured on cattle in a district with endemic leptospirosis. These leptospirae proved to be of the grippo-typhosa serotype.

Three years later, van der Hoeden (1958), working in North Africa, recovered leptospirae of the canicola serotype from *Rhipicephalus sanguicola* ticks captured on ostensibly healthy hedgehogs.

From 1955 through 1959, Y. A. Blagodarny (1961) examined *Ixodes* and *Argas* ticks (7 species in all) and fleas captured on neat cattle, horses, camels, sheep, yellow susliks, gerbils, polecats and in burrows found in districts with endemic leptospirosis—in the foot-hills of the Zailiisky and Dzhungarsky Ala Tau and on the northern outskirts of the Muyunkumy desert. In burrows of the large gerbil (Fig. 16) found in the Batysh-Kuduk locality in this part of the above desert *Ornithodoros tartakovskyi* ticks were captured and leptospirae identical with the "Kazakhstan's II" serotype were recovered from them. Leptospirae of the same serotype were also recovered from the steppe tortoise (Testudo horsfieldi—Fig. 64).

The large gerbil (Fig. 15), the steppe tortoise, and the *O. tartakovskyi* tick are biocoenotically associated, which gives one reason to suppose a circulation of leptospirae in appropriate biocoenoses of leptospirosis foci in the Muyunkumy desert. As correctly conclud-

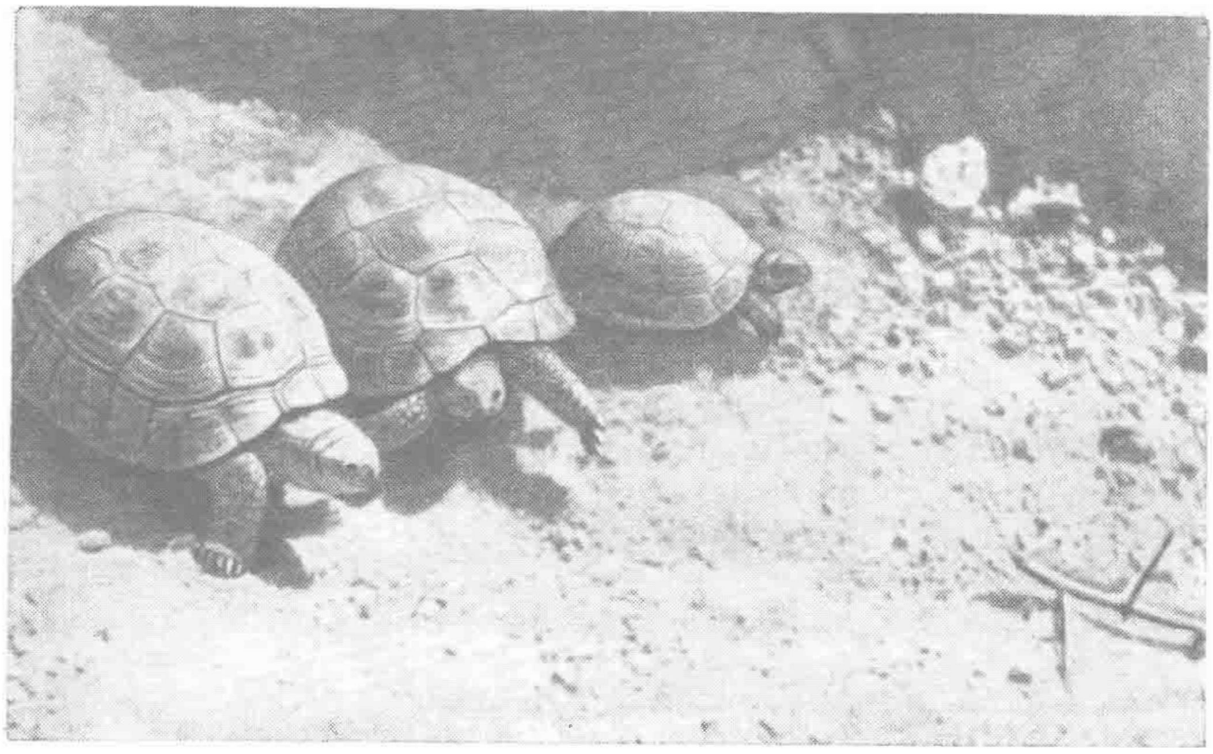


Fig. 64. Steppe tortoises *Testudo horsfieldi*. Photo by P. A. Petrishcheva.

ed by Y. A. Blagodarny, it is necessary to make an experimental study of the role of ticks as a vehicle in leptospira transmission in leptospirosis foci.

Whatever the form of man's infection with leptospirae (through contaminated water, household refuse, or, finally, transmission) leptospirosis undoubtedly belongs to diseases with natural foci since leptospirae may also be carried by various wild animals. For instance, field rodents harbouring leptospirae eliminate them with urine and thereby infect sheaves, hay, etc. When these are handled by people the latter are likely to contract leptospirosis.

## IMPORTED DISEASES WITH NATURAL FOCI

### Q FEVER (RICKETTSIOSIS)

Certain diseases which are in effect diseases with natural foci may be easily imported with infected livestock to new territories. Thus, Czech epidemiologists believe that for North-Western Czechia Q fever is truly a new disease which came on the scene after sheep had been imported into this region in 1949-1950 from a foreign country where the incidence of Q fever was fairly high. A detailed study of the epidemics and epizootics which broke out in Czechoslovakia corroborated the suggestion advanced as far back as 1954 that an infection of anthropurgic origin may spring up in nature, in heretofore unaffected districts, i.e., resume its initial character as a disease with natural foci. The latter may take place in case of trans-

mission of the disease from infected livestock to wild animals on pastures inhabited by small rodents and visited occasionally by larger wild beasts.

Such transmission is favoured by *Coxiella burneti*, the causal agent of Q fever, being eliminated into the external environment by infective animals with the urine, feces as well as with the placenta and amniotic fluid from calving cows and yeaning sheep. *Coxiellae* are rather stable as regards their survival in the external environment. In dried-up infected urine, *Coxiellae* retain their virulence for several weeks. They easily survive both on dry and wet substrate. In the first case, infection may be borne by dust, and, indeed, it has been possible to recover *Coxiellae* from dust in the air. Therefore, besides various other routes of infection, the respiratory route (i.e., inhalation of infective dust) is rather important.

Under laboratory conditions, in blood taken from infected guinea pigs and kept in a vessel under a layer of petrolatum oil in experiments made by Combiesco and his collaborators (Combiesco et Dimitresco, 1949) *Coxiellae* were found to retain their pathogenicity to animals for more than 9 months. The causal agent of Q fever is also spread by tick vectors which eliminate it with their feces quickly drying up in the air. Philip (1948) found dry feces of the tick *Dermacentor andersoni* to remain infective at room temperature for 586 days after the experiment had been started.

*Coxiellae* are highly virulent organisms and invade the recipient by various routes: besides the air passages, as has been mentioned above, they enter the body through the mucous membranes, intact skin (Zdrodovsky, 1955), mouth and are transmitted by vectors—*Ixodes* and gamasid ticks. An infection of alimentary origin may take place in young animals suckling milk from an infective mother, and in humans drinking unboiled milk from infective animals and eating products made from it (butter, cheese). Infection can also be acquired by man when handling raw materials of animal origin (wool, skins and hides, meat at an abattoir) and cotton, as well as when changing bedding for cattle, gathering manure, working at grain and fodder storages, etc.

Many cases are known of natural *Coxiella* infection in various wild animals, for example, sand rats, pigeons, and ticks (Tarasevich, 1955, 1956); the latter transmit the pathogenic agent by inoculation, i.e., through the bite, and eliminate it with their feces in great numbers. Hamsters and susliks are very prone to this infection also.

It is quite natural that imported livestock with latent Q fever contaminate pastureland, infecting various wild animals and tick vectors when their corresponding species are present as members of the biocoenosis in a particular pasture. Given all these factors in combination, a focus of Q fever springs up in a pasture, i.e., in nature, by way of a reverse migration of the pathogenic agent from farm animals to wild (exoanthropic) animals and tick vectors. All this

brings about a revival of *Coxiella* circulation in the biocoenosis of pastures which is followed by infection of fresh herds of cattle put to graze on contaminated pastureland and, finally, to infection of man.

If Q fever is an imported disease in the above-discussed cases, it is indigenous somewhere else for the character of its foci.

### SPIROCHETOSIS OF DOMESTIC FOWL

The latest findings in nature compel one to take a different view, among other things, of the development of domestic fowl spirochetosis the causal agent of which is transmitted by the southern tick *Argas persicus*. This tick has long since been considered synanthropic and, indeed, it has always been found near human dwellings in hen-coops where it usually lodges in cracks and slits of perches, often climbing deep into narrow fissures. One may even talk with good reason about argas ticks being specially pleased to feel cramped by the walls of the fissure in which they take shelter. They owe their ability to climb into narrow clefts to their numerous dorso-ventral muscles connecting in stems the internal surfaces of their spinal and abdominal integument. When contracting these muscles or ejecting blood, the inflated body of an engorged tick flattens somewhat, allowing it to climb into narrow spaces.

Investigations of the past few years have shown that the *Argas persicus* ticks dwell not only in various parts of a farmstead but also in uncultivated areas even those lying far from inhabited localities, for instance, in the steep loess banks of rivers and in the substrate of nest-burrows of rollers, bee-eaters, nuthatches, swallows, doves, and other birds. During a survey of the Muyunkumy desert M. P. Yakunin discovered a grove of alternate-leaved poplars (full-grown and young trees) in the Topachan locality. This turang grove (Fig. 65) had for a number of years been the abode of a large colony of *Corvus frugilegus* rooks; *A. persicus* ticks were discovered here in 1957 in cracks and fissures of tree bark, in hollow trees and in the litter of birds' nests. These ticks were also found on birds nesting in the grove. More than 400 *A. persicus* larvae were found on some birds.

Although these ticks live, as a rule, outside the host, cases are known of adult ticks being found under the wings of domestic fowl brought to the Tashkent bazaar for sale (from materials collected by E. N. Pavlovsky).

In the above-mentioned turang grove, a number of experiments were made with feeding *A. persicus* ticks on various species of wild and domestic fowl, such as chickens, geese, turkeys, pheasants, partridges, wild ducks, jackdaws, rooks, sparrows, turtle-doves, and other birds. All of them proved susceptible to spirochetosis, whereas guinea fowls, pigeons and carnivorous birds proved resistant even to direct injections of large doses of spirochete-infected blood. In the same grove, rooks were found to die in numbers from spiro-

Fig. 65. A turang grove in Muyunkumy, Kazakhstan. Photo by I. G. Galuzo.

chetosis and spirochetes recovered from them proved pathogenic to geese, ducks, chickens, turkeys, jackdaws (Yakunin, 1961).

Consequently, the turang grove in the Muyunkumy desert is *a natural focus of spirochetosis* of birds, which radically changes the former concepts of the epizootiology of this disease. The turang grove is something like an oasis used by migrating birds as a stop-off point. It is also visited by synanthropic birds.

A bird settling on a tree in this grove is attacked by hungry *A. persicus* larvae which feed or at least stay on the bird for 10 days and longer. During this time, the host bird, for example, a sparrow, may fly to a village, thereby bringing into a synanthropic situation *A. persicus* larvae naturally infected with spirochetes in a natural focus of this avian disease.

All this proves the need for an extensive research into what seems to be settled problems of epizootiology.

### YELLOW FEVER AND DENGUE FEVER

Yellow fever may occur in outbreaks in such places as lie far outside the area of habitats of the *Aëdes aegypti* (*Aë. argenteus*) mosquitoes disseminating it. A virus-infected mosquito apparently remains infective for humans for 23 days and longer. During this long period, *Aë. aegypti* (*Aë. argenteus*) may travel on ships from American seaports to far-away places where it attacks man and causes outbreaks of yellow fever. Such outbreaks, which took a heavy

toll of lives, have been recorded in history. For example, in Cadiz (Spain) about 10,000 people died from yellow fever in 1741, in Barcelona 25,000 died in 1824; large outbreaks also occurred in Lisbon (Portugal) and in different seaports of Italy, France, and Britain.

Such outbreaks of yellow fever in uncommon places should by no means be regarded as the appearance of new natural foci of disease by extension from those of America.

The basic factor was the number of viruliferous *Aë. aegypti* (*Aë. argenteus*) mosquitoes brought to European seaports from America. Indeed, each case of yellow fever was due to the bite of an infective mosquito. An outbreak could not spead farther in a new place, since yellow fever cannot be contracted by man from man and natural foci of this disease cannot arise on the site of an outbreak for climatic and zoogeographical reasons; therefore, the outbreak finally comes to an end.

If it so happened in spite of the comparatively slow movement of sailing ships, one can easily realize the multiplied risks of such outbreaks recurring and growing as a result of the development of air travel which has brought distant continents closer to one another and can well be used by *Aë. aegypti* (*Aë. argenteus*) mosquitoes (and other insects) for their migration. That is why international agreements have been signed for a compulsory disinfection of aircraft with a pulverized DDT solution paralysing mosquitoes at destination points on routes leading from mosquito-infested localities. The author happened to see such an agreement in action at Karachi during his flight as a member of the Soviet delegation to the All-India Scientific Congress in Delhi soon after the end of World War II. The first man who hastily entered the plane at the airfield was a local PCO. It was not before he sprayed the gangway with a DDT solution that the customs and quarantine officers came aboard.

*Aë. aegypti* (*Aë. argenteus*) mosquitoes are also a vehicle in the spread of another virus disease known as Dengue fever, or seven-day fever. Among the geographical regions close to the U.S.S.R. this disease occurs in the Balkan Peninsula. Generally, it is the most common in the tropical countries. The mortality rate of this disease is approximately 1 per 1,000.

The last major outbreak of Dengue fever took place in Greece in 1928 when 960,000 people were taken ill and 1,600 died. The danger of infective *Aë. aegypti* mosquitoes being brought on ships to the Black Sea coast of the U.S.S.R. (where *Aë. aegypti* were encountered) made it necessary to take appropriate measures, such as sanitary inspection of steamships and feluccas sailing to Soviet southern ports from Dengue fever trouble areas, *Aë. aegypti* control on the Black Sea coast, etc. These measures have proved effective in warding off the risk of this disease being imported to Georgia and Abkhazia where the air temperature (not lower than 18° C) is favourable to the spread of Dengue virus by mosquitoes.

# CHAPTER VI

# NATURAL FOCI OF DISEASES

## THE ORIGIN OF YELLOW FEVER AND JAPANESE ENCEPHALITIS FOCI

An adequate study has been made on the correlation between the rate of infection of mosquitoes—vectors of the yellow fever virus (Fig. 66)—and the virus titer reaching a certain level in the donor blood. The yellow fever virus is transmitted by *Aëdes aegypti* (*Aë. argenteus*) mosquitoes perfectly adapted to urban (implying human) surroundings. They can acquire yellow fever virus from donors in whose blood the virus titer is comparatively low ($10^3$-$10^1$). The vector of yellow fever in its natural foci, for instance, in the jungle on the upper reaches of the Amazon River, is another blood-sucking mosquito, *Haemagogus spalazzani*, which inhabits the crowns of tall trees; for this insect to be infected with yellow fever, a higher virus titer is required in the blood of a wild donor, specifically, of the monkey.

It is precisely the definite amount (titer) of virus required for infection to be carried from donor to vector that accounts for the important circumstance concerning the participation of yellow fever patients in the circulation of its virus in urban surroundings. If the virus titer in the patient's blood falls short of the minimum required for infection to be conveyed from the sufferer to a mosquito vector, such a patient ceases to be a link in the chain of organisms sustaining a continued circulation of the virus in a disease focus.

This by no means implies, however, that a yellow fever patient cannot be a virus donor for mosquito vectors in general. Quite the contrary. There have been cases of intrahospital yellow fever. The example of yellow fever incidence during the construction of the Panama canal is especially illustrative.

The newly-arrived workers contracted various tropical diseases, in particular yellow fever, which took a heavy toll of lives. It is significant that the infection spread even within hospital wards. Finally, the cause of it was uncovered. It was found that the legs

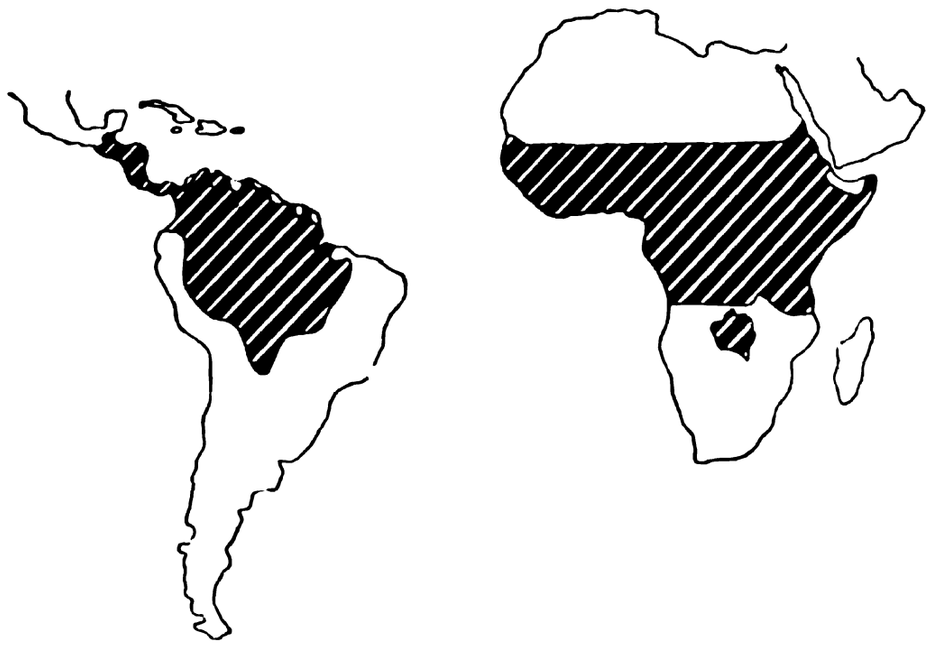


Fig. 66. Chart of yellow fever distribution. According to WHO, 1952.

of hospital beds stood in cups filled with water to keep off termites. *Aë. aegypti* (*Aë. argenteus*) mosquitoes perfectly adapted to life and development within human dwellings freely entered the wards where they attacked patients and also found water in the cups where to lay eggs. Their developmental cycle is short, especially in the tropical zone; therefore, mosquito vectors were able to hatch within hospital wards, where they found a plentiful source of food on patients with yellow fever and sufferers from other diseases. It was only natural that they acquired the virus from the former and passed it on to the latter.

The situation was improved by spreading nets over the ward windows and doors and adding kerosene to the water in the cups. The kerosene film formed on its surface made this water unfit for the development of yellow fever mosquitoes. Such measures were taken in hospitals but in the household one cannot do without water storage; moreover, in a disorderly household, usually in the backyard, there is a litter of broken crockery, empty tins, etc., in which water collects and immediately attracts "domestic" *Aë. aegypti* (*Aë. argenteus*) mosquitoes, these dangerous vectors of yellow fever virus *.

Things do not look better at sites where hand-made pottery is produced and open vessels of varied shape are kept out-of-doors, in which water collects and serves as a breeding place for various species of mosquitoes—vectors of the Japanese (mosquito-borne) encephalitis virus (Fig. 67). This is observed in the Liaotung Peninsula.

* For extension of yellow fever foci see p. 144

Fig. 67. Pottery in a courtyard. The Liaotung Peninsula. Photo by P. A. Petrishcheva.

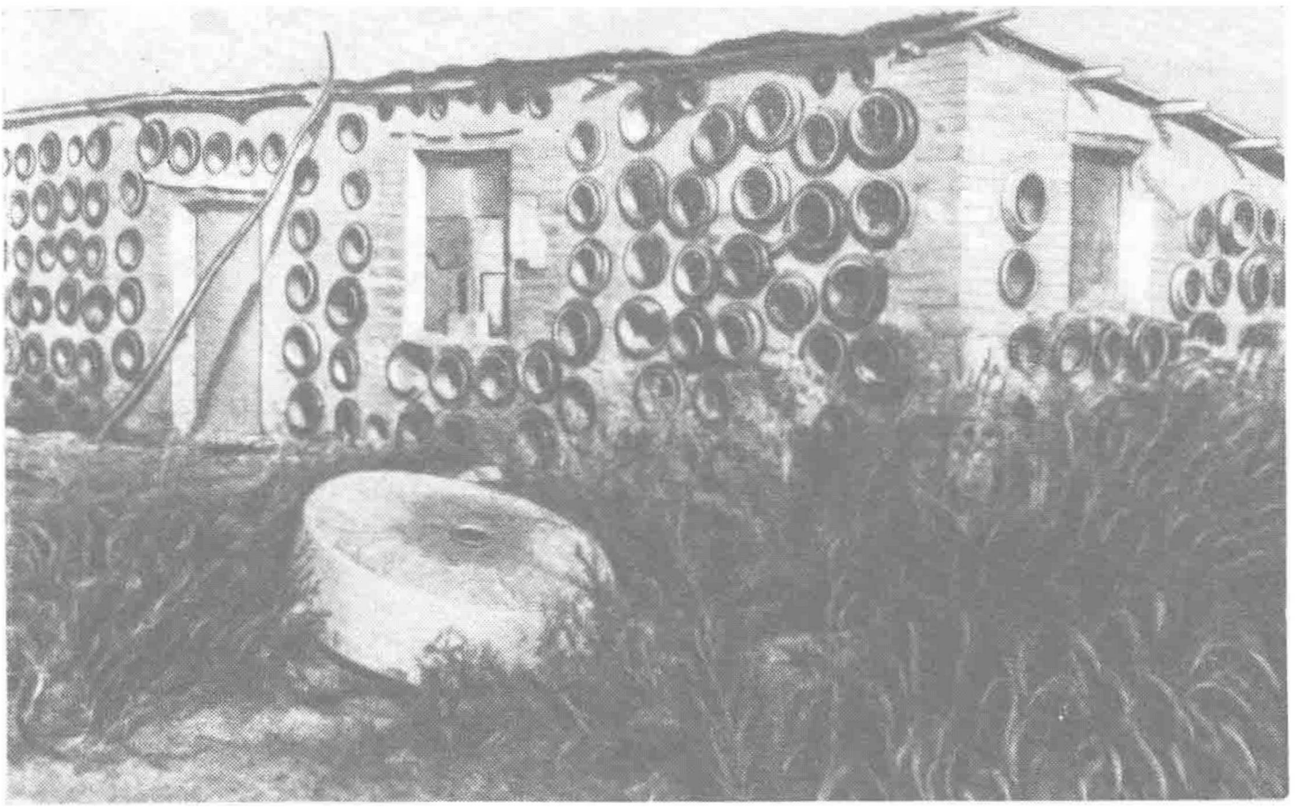


Fig. 68. A characteristic structure with a wall made of open fireclay cylinders in which water collects and mosquitoes—vectors of mosquito-borne encephalitis—are hatched. Liaotung Peninsula. Photo by P. A. Petrishcheva.

There are also other factors, depending on man, which contribute to this health hazard. There is an age-old method of building the walls of primitive houses, fences, etc., from rather large fireclay cylinders open at one end and placed in rows one upon another to a required height, the spaces in between being filled with some brickwork. Such a wall looks like an empty honeycomb set on end (Fig. 68). Water collects in the horizontally placed cylinders in quantities sufficient for mosquitoes—vectors of Japanese encephalitis—to be hatched there, in direct proximity to man.

But let us revert to the subject of mosquitoes—vectors of the yellow fever virus. While it is comparatively easy to clean up a backyard, clearing off broken pottery and useless tins, there is still need for a store of water for use in the household. Water barrels are immediately infested by the aquatic stages of the *Aë. aegypti* (*Aë. argenteus*) mosquito.

The destruction of the vector in every stage of its metamorphosis is an indispensable and highly important part of any yellow fever control measure. Therefore, in such countries as Brazil, where a special water inspection has been instituted for checking the cleanness of land from all sorts of useless water reservoirs suited for mosquito breeding, tropical gambusia-fish are released into drinking and household water receptacles in numbers varying with the latter's sizes, and devour both mosquito larvae and pupae.

Such treatment is applied to larger water reservoirs also (ponds, rice plantations, etc.). In the U.S.S.R., gambusia-fish brought from Italy by Dr. Rukhadze were bred on a wide scale in Abkhazia; similar experiments were made in Turkmenia by P. A. Petrishcheva for the purpose of malaria control.

## THE ORIGINATION OF NEW NATURAL FOCI BY EXTENSION TO MAN UNDER SPECIFIC CIRCUMSTANCES

It is important to know whether new foci of disease can appear in nature. This question has the following two aspects: (1) whether a new disease focus, formerly non-existent on earth, comes into being in nature or (2) whether a formerly unknown natural focus is uncovered in a certain area owing to new social circumstances, such as development of research, the settlement of a non-immune population in the area of a formerly latent natural focus of disease. If there are no people, there is no disease! For example, during the building of a road in the taiga, cases of disease in the first year of work were isolated, in the next year they grew in number owing to the workers' constant exposure to natural hazards, in the third year the disease incidence attained the highest point. Meanwhile, work was started in clearing the taiga on both sides of the road, i.e., the surroundings began to be reclaimed from their virgin state, and this brought about a decline in morbidity.

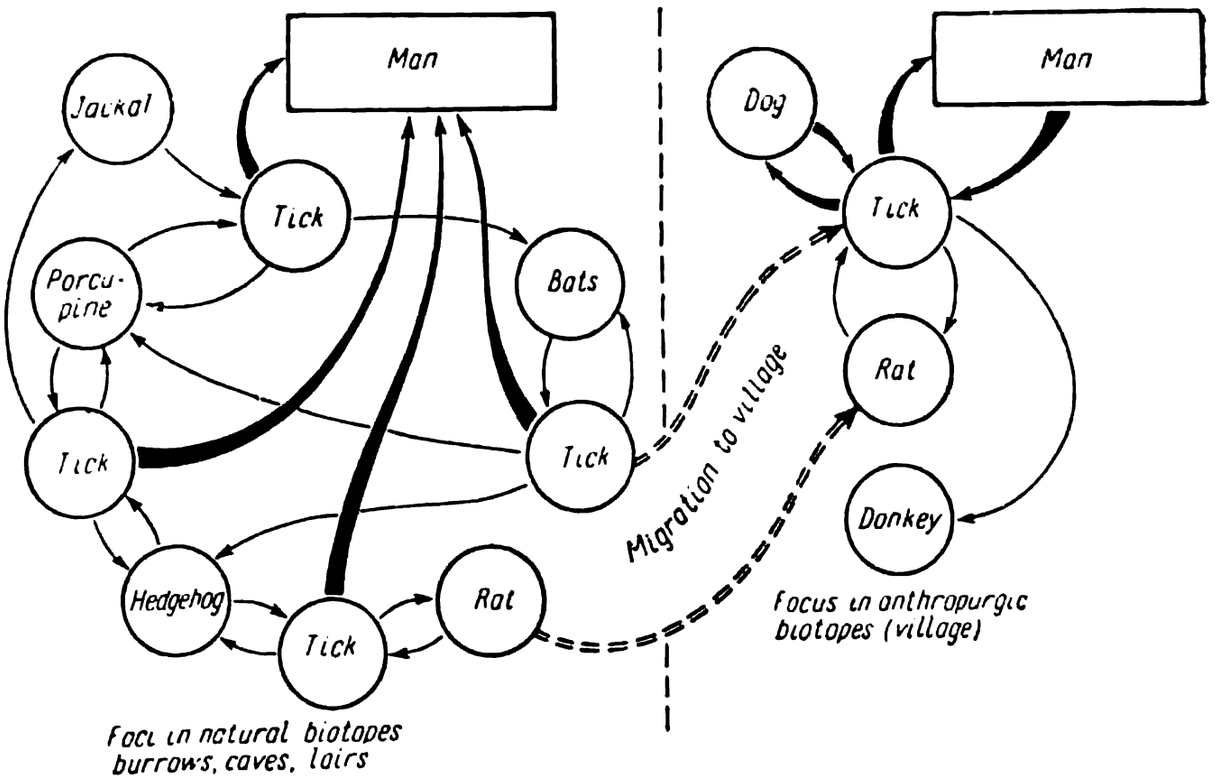



Fig. 69. The circulation of tick-borne relapsing fever spirochetes in the biotopes of a natural focus and the latter's extension to anthropurgic conditions (village) as a result of migration of a tick (*Ornithodoros papillipes*) and its host (here a rat) to the village. According to E. N. Pavlovsky.

It is possible that a new focus of disease may arise in nature by extension from a known focus of long standing (Fig. 69). This depends on the characteristic behaviour of the specific vector of a disease with natural foci. Discussed above were the characteristics of the biology of the tick *Ornithodoros papillipes*, a vector of tick-borne spirochetosis in Central Asia, its reluctance to active migration and firm connection with its habitat in the external environment.

Winged bloodsucking dipterous vectors, however, can travel far from the natural focus of a transmissible disease with which they are closely associated both during their metamorphosis and in the habitat of their adult stage. An example in point would be sandfly and rodent burrows in a southern desert; the entire metamorphosis of sandflies takes place within burrows in which sandfly females deposit eggs, larvae hatch, feed on dry rodent feces, transform into pupae and the latter into adult females and males. Sandfly females may bite rodents—hosts of the burrow—and their young inside the burrow itself. Rodents of certain species (*Rhombomys opimus*, *Spermophilopsis leptodactylus*) are liable to skin leishmaniasis. Sandfly females biting them acquire the agent of skin leishmaniasis—*Leishmania tropica*; at nightfall females leave the burrow and may fly as far as 1.5 kilometres away. They return at dawn to their former or any other burrow they are likely to find and attack

its host, infecting it with skin leishmaniasis thereby giving rise to a new elementary focus of this disease.

It is known that people staying the night in a semi-desert may be bitten by sandflies and infected with Penjdeh sore. So when a new human settlement, for instance, a poultry farm, is set up in a semi-desert, sandflies take up residence in these new surroundings favourable to their living and give rise to a rural form of Penjdeh sore.

Foci of transmissible anthroponoses, malaria in particular, may also spring up anew in new places and new circumstances. Thus, after a canal had been built from the Amu-Darya river to the Kara Kum sand desert, malarial mosquito larvae migrated there passively with the water stream, and nothing interfered with their subsequent metamorphosis. Moreover, cattle herds driven to new areas are followed by female malarial mosquito imagoes. In new localities they take shelter during the day in burrows of gerbils and other desert rodents. Mosquitoes feed on cattle and humans. If gamete-carriers are found among the latter, i.e., individuals recovered from malaria and laden with sexually immature forms of the malarial parasite (plasmodium), *Anopheles* females will, upon ingestion of their blood, become infective to man; that is how fresh cases of malaria may occur in a new locality.

Yet there is another way for a malaria focus to spring up in a desert. Studies by P. A. Petrishcheva in the Karakumy desert have shown that malarial mosquitoes at places live in the depth of the desert, taking refuge in well pipes. Human gamete-carriers appearing in such places bring along a new element—the malarial parasite, which formerly was non-existent here, and, therefore, *Anopheles* inhabitants of the desert were sterile as regards the presence of malarial parasites in their salivary fluid. The latter appear in the desert upon the arrival of man containing gametes of the malarial plasmodium in his blood. They certainly gain access to the gut of mosquitoes—specific vectors of malaria and since in summer the air temperature in the desert is favourable for their development the parasite completes its sexual reproduction cycle inside these mosquitoes. The *Anopheles* mosquito acquires an infective power and becomes dangerous for new arrivals who have not been ill with malaria before. They are bitten by *Anopheles* females infected in the desert and contract malaria. This may give rise to a new malaria focus as a result of its agents being introduced into a new place and subsequently transmitted by local malarial mosquitoes (P. A. Petrishcheva).

New foci of disease may appear among new species of animals brought to replace other animals kept in a given locality. For example, a territory formerly used to keep swine affected with erysipelas (caused by *B. rhusiopathiae suis*) may become a source of this infection for ducks settled on it. Some time after ducks have been put on such a territory they refuse to take food, ruffle their feathers, develop

diarrhea and die in 3 to 4 days' time. The microbe of pig erysipelas was recovered from some dead ducks (Tregubova, 1961, p. 51).

All this may take place if the pathogenic agent retains its infectivity in the external environment long enough. That is why special importance is attached to the study of the causative organisms of any nature whatsoever which are discharged into the external environment and to the term of their virulence (see pp. 64-65).

## CONJUGATE DISEASE FOCI

Since the existence of conjugate natural foci of disease has been brought to light one may expect simultaneous infection of man and animals with two diseases. The possibility of such cases is easier to explore experimentally, by infecting animals with the causative agents of two or more diseases. This method has been used by Z. D. Khakhina, A. G. Somova, V. A. Silich, I. I. Polyakov and L. G. Gerasyuk (Somova, Silich et al., 1959; Polyakov, Somova et al., 1959; Khakhina, Somova et al., 1960), who induced a mixed infection in guinea pigs by inoculating them with the causal agents of Q fever and brucellosis. The literature contains a report by Victor, Mika and Goodlow (1955) to the effect that simultaneous aerogenous infection of guinea pigs with brucellae (*Br. suis*) and *Rickettsiae burneti* causes less extensive morphological changes in these animals than do brucellae alone. Hence the conclusion, based, it is true, on the author's theory of parasitocoenosis, that Burnett's rickettsiae in vivo do not contribute to the common manifestations of brucellosis, as though restricting the influence of brucellae on the infected organism to a certain extent.

The aforesaid investigators have shown in their collective research that in case of the above-mentioned mixed infection with Burnett's rickettsiae and *Brucellae suis* the course of the disease in guinea pigs deviated from that taken by a disease caused by one of these organisms. In particular, the body of a guinea pig became cleansed from Burnett's rickettsiae in case of a mixed infection within a shorter time than when it had been infected with Q fever rickettsiae alone. In simultaneous infection with both organisms or in preliminary infection with Q rickettsiosis followed by infection of the same animal with brucellae, the latter exhibited less virulence and the pathomorphological changes in the guinea pig body were less extensive than when these infections had been induced separately.

Such changes had a definite relation to time. When the second infection was induced in a month's time after the first one the deviations from the usual course of brucellosis were the most apparent: the development of brucellosis infection in a guinea pig preliminarily infected with Q fever markedly lagged behind that seen in control animals. In like manner, the pathomorphological changes

typical of brucellosis occurred at a later time, and their reversal was faster than in control animals.

In case of infection in the reverse sequence, i.e., with Q fever following brucellosis, the former's clinical course changed also.

Something similar is observed also in chronic dysentery concurrent with helminthic protozoan, and mixed invasions.

It has been noted that most of the repeatedly admitted patients with dysentery suffer from helminthiasis, protozoiasis and mixed invasions which "points to the influence of these ... invasions on the development of chronic forms of dysentery and to the need for appropriate therapy" (Toporkov, 1961, p. 45). This author considers helminthic, protozoan or mixed invasions to be the possible cause of dysentery taking a chronic and recidivating course in some patients. For instance, one dysentery patient was found to harbour whip worms, two others *Lambliae*, still another ascarides; ascarides together with *Trichomonas* were found in one patient, teniae and *Lambliae* in one, and trichostrongyloides also in one. Ten chronic dysentery patients suffered from chronic anacid gastritis and two others from chronic hepatitis. The author supposes the latter two diseases to have been sequels of chronic dysentery.

*Reciprocal exclusion* is usually observed also in simultaneous infection of a bacterium with two unrelated phages (mixed infection), only one of the phages undergoing multiplication. If the bacterium is infected with such a non-multiplying phage several minutes before it is infected with the phage producing a stronger effect (successive infection) the suppressed phage will be provided with preferential conditions for its multiplication. In case of a mixed infection of a bacterium with two related phages both of them will multiply. If the infecting phages are not very intimately related, an incomplete exclusion is noted: the mechanism of reciprocal and incomplete exclusion is so far uncertain (Adams, 1961).

## THE FORMATION OF SECONDARY NATURAL FOCI OF TRANSMISSIBLE DISEASES

The causative agents of certain diseases with natural foci may be brought back to nature fro[illegible]man surroundings as a result of both wild mammals and arth[illegible]ctors acting as links in the chain of their circulatio[illegible]961).

This phenomenon is concerned[illegible]ular, with the problem of origination of se[illegible]dary diseas[illegible]nature.

A concrete exampl[illegible] of this is the[illegible]e of a natural focus of Q fever in a district of the Leningr[illegible]on concurrently with a focus of tick-borne encephalitis. It may have been originally caused by farm animals with Q fever being brought there. Some

time later, a rickettsia culture was obtained from a yellow-necked mouse captured in a village and a year after, from a field mouse caught in a place lying one kilometre away from the village. *Coxiellae* were also recovered from *Ixodes ricinus* ticks in 1959, whereas in 1958 similar attempts were unsuccessful. Apparently, both rodents and ticks living there became involved in the chain of organisms through which the circulation of *Coxiellae* takes place in nature; in other words, there is evidence of a new natural focus of Q fever having formed as a result of the contact established between wild and farm animals (Tokarevich et al., 1961) rather than by extension from an existing natural focus of this disease.

A distinguishing feature of Q fever is the great role played in its spread by the anthropurgic factor, i.e., by everything directly or indirectly connected with man, for instance, driving cattle with cases of latent infection to new areas, work at cattle farms with inadequate hygienic standards, importation of agricultural produce (wool, cotton), work at slaughter-houses and meat-packing plants and at fulling mills where workers are exposed to infection during primary sorting of raw wool, etc. Man contracts Q fever by contact, and animals also by inoculation, i. e., through the agency of vectors.

## THE LIMITS OF EXTENSION OF NATURAL DISEASE FOCI TO REMOTE AND NEW TERRITORIES

This depends on the mobility of animal donors and recipients of infection (local and distant migrations of mammals and birds) and corresponding vectors of the pathogenic agents.

Vectors can be subdivided into two groups: (1) freely moving and highly mobile species—winged insects, mainly dipterans, and (2) crawling vectors with limited mobility, mainly ticks.

### LOCAL AND DISTANT MIGRATIONS OF MAMMALS

Limited passage within the area of their habitat is also important for various mammals, for example, the passage of large gerbils from one burrow to another (Figs. 39, 40). The mobility of rodents depends on the weather. Good weather with adequate humidity favours the growth of vegetation and rodents do not have to search for scanty edible plants. Consequently, their mobility lessens and physiological conditions improve due to adequate nourishment. Therefore, only small local epizootics arise which fail to extend to neighbouring areas. This was the case, for example, in more humid years in the Murgab delta section of the Central Asian lowland natural focus of plague. But migrations of wild animals are important as such, which concerns certain species of rodents in certain places.

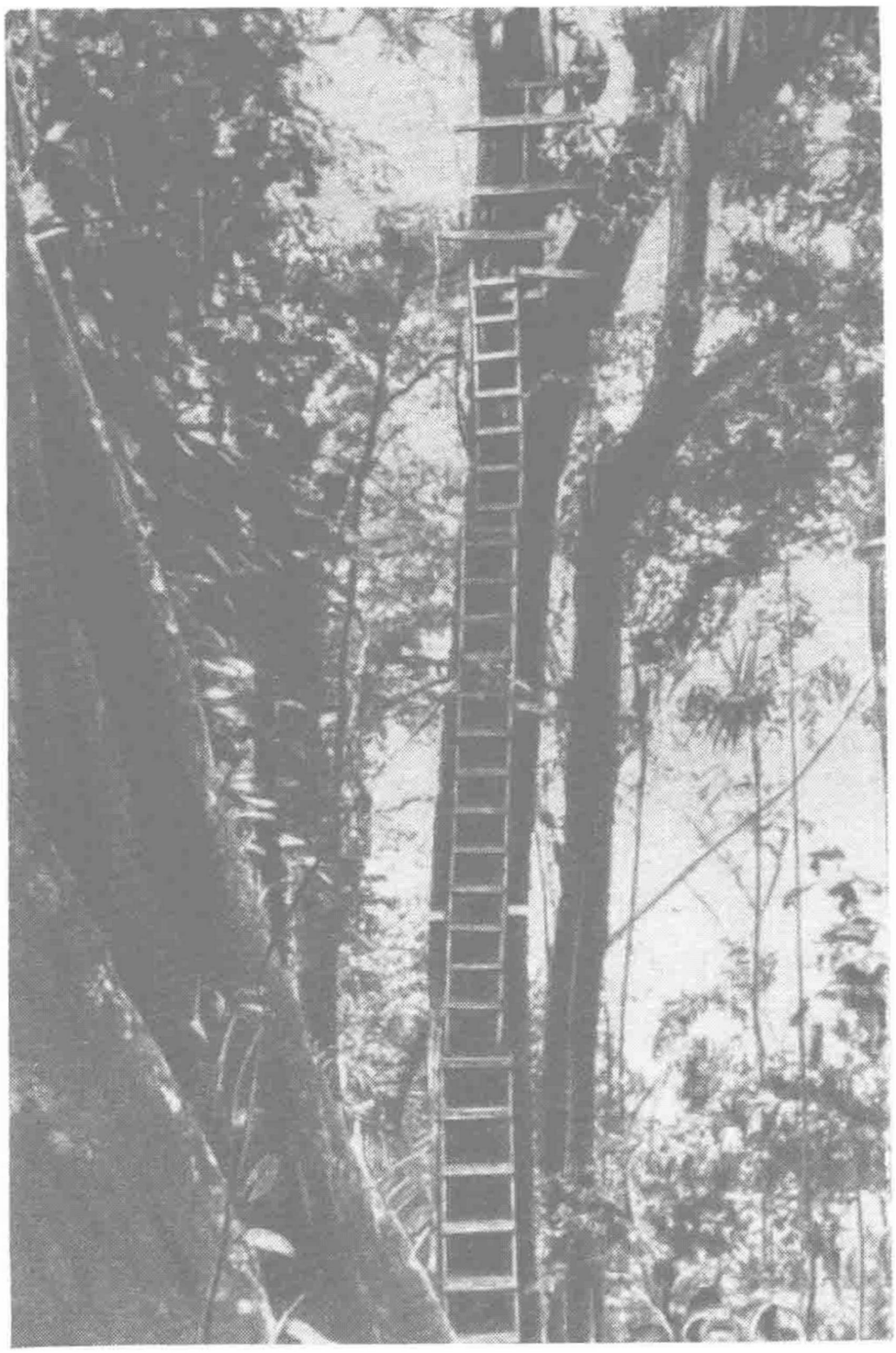


Fig. 70. A ladder and platform for capturing *Haemagogus* mosquitoes at a height of 44 feet above ground (Cerra la Victoria, South America). According to Galindo, Trapido and Carpenter (1950).

Thus, G. I. Demina, E. P. Demin, Z. I. Shchekunova (1961) raised the question of the need to step up epidemic control measures in the regions of the Mountainous Altai Autonomous region bordering on the western part of the Mongolian People's Republic in view of a possible migration of Mongolian pikas infected with plague by tarabagans from Mongolian to Soviet territory.

Certain mammals are known to undertake spontaneous mass migrations sometimes, for example, lemmings. During years of

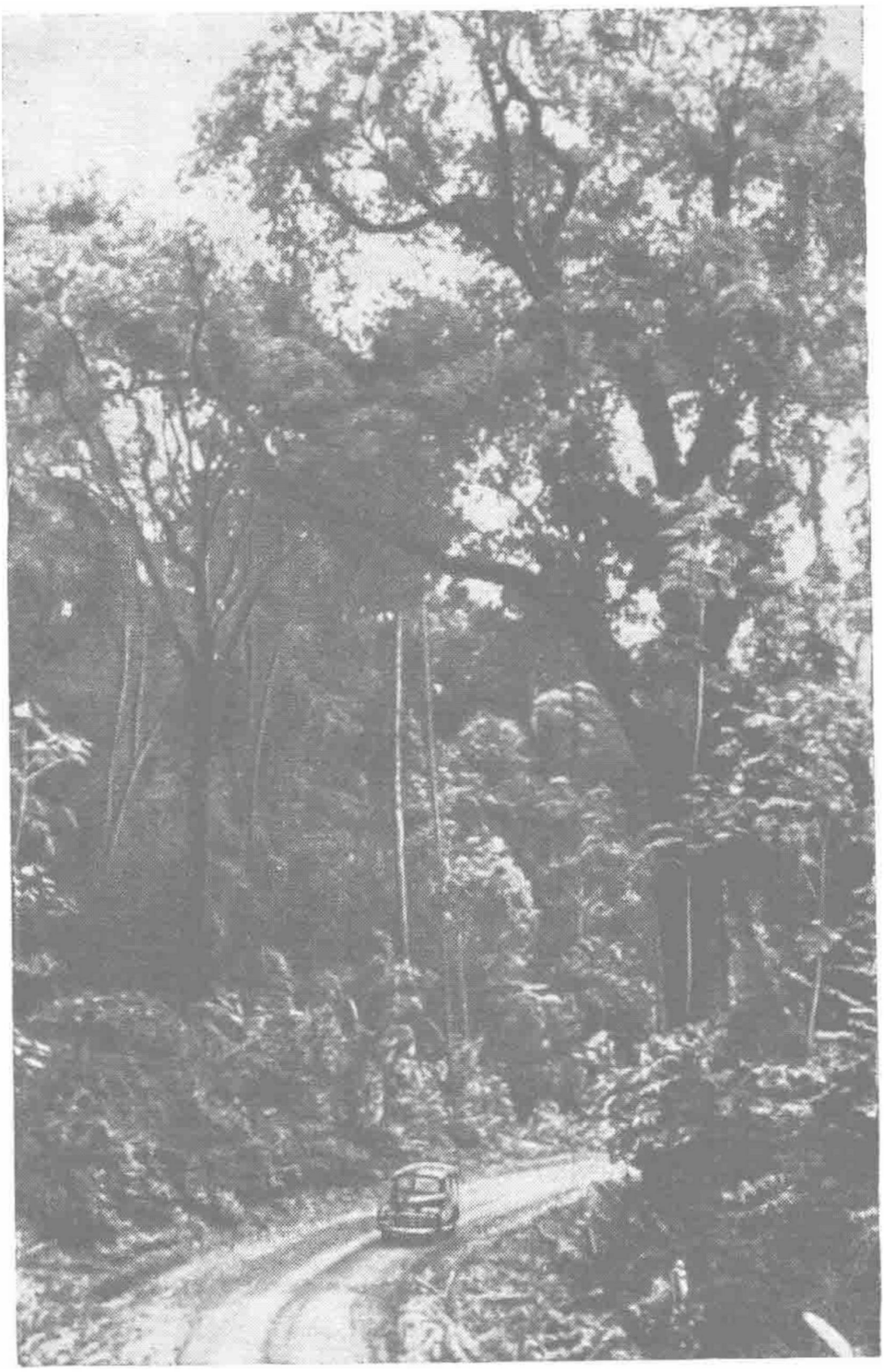


Fig. 71. A tall-crown forest in South America (in the environs of Cerra la Victoria) with a continuous tangle of crowns 80-100 feet above ground and higher. The crowns are the habitat of *Haemagogus* mosquitoes and *Aotus* monkeys, which are known to come down on land. According to Galindo, Trapido and Carpenter (1950).

their mass reproduction when vegetable food is consumed in quantity and becomes scanty, lemmings begin to migrate southwards from their usual habitats in the tundra. They may be infected with tularemia, and such spontaneous migration of these northern rodents contributes to the spread of this disease, since local animals and

insects (gadflies) capable of receiving and transmitting the infection may be found at the final point of migration.

In the case of yellow fever, the behaviour of monkeys is an important factor contributing to its transmission. For its origin, yellow fever is undeniably a disease with natural foci. The *Aotus* monkeys are highly susceptible to its virus. These monkeys play an especially important role in the epidemiology of yellow fever in the forests of Colombia. The local vector of its virus is the acrodendrophilic (i.e., living in the crowns of tall trees) mosquito *Haemagogus capricorni*. To capture it for examination and experiments ladders were built alongside of tree trunks, with platforms to accommodate a man collecting mosquitoes. For example, the first of such platforms was made at a height of 25 feet above ground, the second at 45 feet, etc. (Fig. 70). Forest trees in the locality where the studies were carried out (Cerra la Victoria) had their crowns intertwined to form a kind of a roof at a height of 80 to 100 feet above ground (Fig. 71).

*Haemagogus* mosquitoes and monkeys dwell in tree crowns where the yellow fever virus may be transmitted by mosquitoes from monkey to monkey irrespective of man. This is evidence of a natural focus of yellow fever existing in high tree crowns. Laboratory experiments have shown that a mosquito passes on the virus not immediately after it has acquired it from an infective monkey, but after different periods varying with the environmental temperature: at 24-27°C after 22-24 days and at 30°C after 13-15 days. Only part of the mosquitoes fed on monkeys acquire an infective power (Bates a. Roca-Garcia, 1945).

Acrodendrophilic mosquitoes are prone to attack people climbing specially built ladders towards the tree crowns, yet it is quite probable that these mosquitoes have some other hosts serving as an intermediate link connecting the natural foci of yellow fever in trees with those on the ground.

In the Amazon jungle, the donors of yellow fever virus are monkeys and various animals, typical for South America, for example, opossums.

When a village has sprung up in the jungle, yellow fever virus may be transmitted to man by forest mosquito vectors from monkeys which often come down to the ground.

Monkeys often raid plantations lying closer to towns, and finally the disease extends to towns where the virus is transmitted by the *Aëdes aegypti* (*Aë. argenteus Poir*) domestic mosquitoes.

Consequently, the infection of humans with yellow fever (although occurring on a mass scale sometimes) is in effect the result of *a secondary involvement of man in a modified cycle of yellow fever virus circulation initially taking place in natural foci; yet for all its subordinate character this phenomenon is a major health hazard to man.*

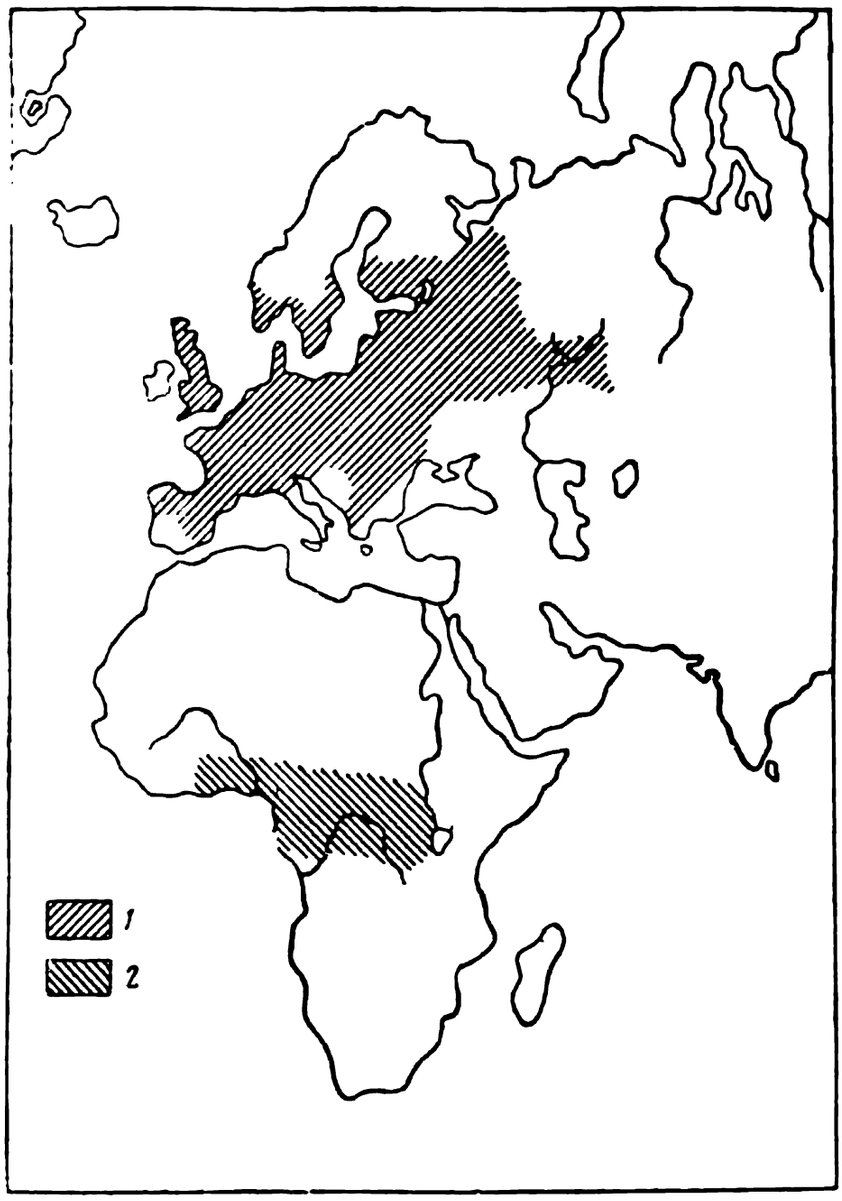



Fig. 72. The migration of *Phylloscopus sibilatrix*. Possible importation of ticks and viruses from Africa to Europe. According to Hoogstraal and others (1963).

*1*—regions of estivation; *2*—regions of hibernation.

### MIGRATION OF BIRDS

Another factor in the spread of this disease is the regular migration of birds along routes established in the process of evolution—from north to south to the subtropics and tropics in autumn and in the reverse direction in spring (Fig. 72). Various examples have been given above of the epidemiological significance of birds, which may be donors as well as recipients of various virus infections. Some virus diseases have a very wide meridional prevalence. One example is equine encephalomyelitis (although rarely occurring in man) whose natural foci, as has been described above, are associated exclusively with birds for the character of its vectors. This disease is of frequent occurrence on the Atlantic coast of North America

and is encountered in South America as well, in particular in Brazil. The question arises—is such a wide prevalence of this disease due to the migration of birds infected with its virus?

## EXTENSION OF NATURAL FOCI OF LYMPHOCYTIC CHORIOMENINGITIS

The extension of a natural focus of disease to a town through a suburb and its environs is well illustrated by a study of the origin of a lymphocytic choriomeningitis focus in the northern zone of the European part of the Russian Federation (Zhdanov, 1957). To begin with, V. M. Zhdanov, M. I. Levi, and N. N. Basova (1949) reported seven cases of this disease confirmed by a virological examination: in the houses of four sufferers the virus was recovered from house mice also.

Upon intracerebral infection albino mice are taken ill on the 6th-7th day. In case of a prolonged passage on ablino mice the lymphocytic choriomeningitis virus loses its pathogenicity to guinea pigs but retains its immunogenic properties (Levi, Howard, Traub). This fact enabled Levi and Traub to attenuate the pathogenicity of the virus to a degree where it could be used as a live vaccine for preventing disease in guinea pigs inoculated with large doses of a virus strain pathogenic to them (cited from Schur, 1954, p. 68). In the middle belt of the Russian Federation, house mice can live in the warm season of the year in wild nature where they serve as a reservoir of lymphocytic choriomeningitis virus. In town, lymphocytic choriomeningitis foci are found in apartment houses and industrial premises infested by house mice spontaneously infected with this virus. On the town outskirts common voles and forest mice are met with occasionally (Levi, Kislyakova et al., 1954).

In 1951, an average of 18 per cent of the buildings examined in a town were found to be infested by virus-infected mice. Mice-infested buildings were fewer in the town centre than on the outskirts, and on the latter still fewer than out of town. The vectors of the lymphocytic choriomeningitis virus were, in addition to those described above, also the yellow-necked mouse and the harvest mouse (Basova, Volchanetskaya and Zhitomirskaya, 1954).

Lymphocytic choriomeningitis is in effect a disease with natural foci. A survey of certain places has provided the following picture of the extension of a natural focus of this disease to the town centre. In the floodlands of a river there is a natural focus 80 per cent of whose territory is flooded during high water. At this time, rodents gather in an elevated part of the floodlands as if on an island. No stacks of hay or straw or other convenient shelters are available there. Therefore, they have to climb into old burrows and crevices in the ground, which results in a close intra- and interspecific contact

between them. This contact continues for about a month, until the soil has dried up. During this time, rodents multiply and nurse their young here.

From over 1,700 rodents captured at such natural stations 49 strains of lymphocytic choriomeningitis virus were recovered. It is quite probable that in close contact between rodents of several species lymphocytic choriomeningitis is transmitted from virus carriers to healthy rodents, house mice in particular, by the agency of gamasid ticks. When it grows cold house mice migrate to the town outskirts and to the town itself, carrying lymphocytic choriomeningitis virus, which results in infection of man in buildings infested by virus-loaded gray (house) mice—(Zhdanov, Levi, and Basova, 1949); Levi, Gusev, Kislyakova et al., 1954).

## GEOGRAPHICAL AND PALEOGEOGRAPHICAL DISTRIBUTION OF NATURAL FOCI OF YELLOW FEVER AND OTHER DISEASES

Hirsch' data on the historical spread of yellow fever in four stages from 1635 to 1849 are taken note of to this day. First stage: the disease was discovered in the Antilles (1635-1692); second stage: a large epidemic flared up in these islands (1699-1702); third stage: the spread ("importation") of yellow fever to the North Atlantic region and to Africa, as far as Guinea (1703-1848) and in 1816 as far as the Congo; fourth stage: extension of yellow fever to Brazil (1849). Consequently, according to Hirsch, yellow fever had been brought from the New World to Africa where it spread along the western coast. This, however, fails to explain the subsequent discovery of this disease in Central Africa and in the jungle on the upper reaches of the Amazon River.

Expeditions from the Rockefeller Institute have found the presence of yellow fever virus in monkeys, marsupials, and other animals living in the jungle on the Amazon River. *Aëdes aegypti* mosquitoes were absent there, but they discovered the presence of *Haemagogus* forest mosquito vectors, which was a further advance in the study of jungle yellow fever. The formerly known yellow fever was an urban disease since its vector, the *Aë. aegypti synanthropic* mosquito, had perfectly adapted itself to life in human dwellings and outhouses, depositing eggs even in temporary accumulations of water of negligible size.

The formation of a divided area of yellow fever prevalence (tropical Africa and Brazil as far as the Amozon River, Fig. 66) is given a more reasonable interpretation than that based on the presumption that it was brought by man from one continent to the other. Since the virus of yellow fever is discovered in mammals, the appearance of its pre-existent form may with good reason be traced back to the time preceding the prime in the evolution of mammals on Earth,

i.e., the Paleocene epoch of the Tertiary period (at the latest). It is important to know the territorial correlation of the continents of the Old and the New World at the time. Wegener's hypothesis of North and South America having broken off from a continental massif incorporating Europe and Africa would be suited for explaining the present features of the geographical distribution of yellow fever. It may be assumed that during the existence of the common continental massif yellow fever was already widespread in what would become tropical Africa and South America. After America had broken away from the common continental massif and moved westwards the former common area of yellow fever divided into two parts, so this disease remained both in tropical Africa and Brazil.

Wegener's theory is especially attractive for biogeographers. But Wegener changed his conjectures concerning the time of separation of South America and Africa. At first, he referred this division to the late Eocene or the early Oligocene (Wegener, 1912); later he considered that the continents had separated before the mid-Cretaceous period. L. S. Berg (1947) notes reasonably that "the union of South America and Africa in the early Cretaceous period does not offer an explanation for the present distribution of animals and plants" (p. 24).

And conversely, the existence of the Atlantic range in the Quarternary period (see below) accounts for many features in the geographical distribution of many terrestrial plants and animals.

It has been established today that a submerged mountain range extending from north to south exists on the bed of the Atlantic Ocean, its highest summits rising as high as 1,300 m below sea level. It is reasonable to agree with the view of L. S. Berg (1947) that in discussing problems of the biogeography of the Atlantic countries one should take account of the existence of the submerged Atlantic range some parts of which sunk into the sea as far back as the Quarternary period. Spurs from this mountain range extended both to South America and Africa.

This territorial connection may have contributed to the transmigration of animals from one continent to another, which must have taken place before the Quarternary period, since the difference between the faunas of South America and Africa is quite substantial (Berg, 1947). The same connection may have contributed to the evolutional formation of an extensive common focus of circulation of the yellow fever virus transmitted from one animal to another by bloodsucking mosquito vectors (*Culicidae*).

Certain species of animals, virus donors and recipients, may have remained asymptomatic (apparently healthy) virus carriers. After the Atlantic range had sunk into the sea and the territorial link between South America and Africa had disappeared the former common area of yellow fever prevalence broke in two; this may

account for the present existence of the yellow fever zones of tropical Africa and the Brazilian jungle lying so wide apart. The later evolution of these two foci continued independently, particularly, when man was settling in new places and developing intercontinental routes of travel.

In like manner, hypothetical explanations can be given for the existence of divided areas of some other virus diseases, for example, pappataci fever in the Crimean Peninsula and Asia Minor, etc.

The task of finding the best-grounded explanation for the causes of the basically steady distribution of diseases with natural foci requires a coordinated effort of specialists in epidemiology, clinical medicine, parasitology, bacteriology (including virology), zoology, ecology, geography (including cartography), historical geology, paleontology and historiography. The extent of contributions by representatives of so different sciences should vary with the character of individual problems, yet each study of this kind should be based on a combined effort. The conclusion is as follows.

*The most reliable and demonstrative basis for nosogeography characterizing the specific features of large and small areas is determination of the geographical distribution of natural foci of diseases. Ecologo-parasitological and microbiological analysis of the conditions of their existence associated with a particular geographical landscape makes it possible to find out the indices from which one can reasonably suspect the presence of natural foci of a specific disease even where no cases of it in man have so far been reported. Therefore, preventative measures can be taken in advance prior to settlement in such localities.*

The boundaries of natural foci of diseases are not stable, particularly where different geographical landscapes border on each other or coalesce. In addition, man may inadvertently influence the existence of natural foci of diseases with his day-to-day activities; in some cases he contributes to their elimination (for instance in reclaiming a forestland with tick-borne encephalitis foci), in other cases he may provide conditions for new foci of diseases being formed. It should be added, however, that man can deliberately implement special measures aimed at sterilizing and wiping out natural foci of disease.

The theory of the geographical distribution of natural disease foci, practical methods for their complex field studies, and experience gained in fighting such diseases in the U.S.S.R. have been fully approved in Czechoslovakia. During 4 to 5 years of survey a number of natural foci of diseases were discovered there, although skeptics said it was absurd to suspect such foci in a country with an age-old culture. The reality disproved their views, and natural foci of diseases were found in Czechoslovak territory which had long since been cultivated to the utmost extent. The surveys carried out there contributed significantly to the theory of diseases with natural foci. Czechoslovak biologists, medical and veterinary experts have shown

natural foci of diseases to exist in a modified state in areas cultivated since long ago and demonstrated the practical value of the theory of natural disease foci for determining their geographical distribution and organizing their control. B. B. Rosický's work on these problems won him the Gottwald Prize, the highest government award for scientific research in Czechoslovakia.

The theory of diseases with natural foci can be effectively utilized in any country, especially in the tropics, where both the indigenous and newly-settled populations are harassed by endemic and a number of generally widespread diseases. The first step should be to find out the geographical distribution of the above diseases and make a scientific analysis of its factors. The interest in nosogeography has markedly grown of late as is evidenced by the publication of separate charts of the world-wide distribution of diseases, such as *Atlas of Distribution of Diseases* issued by the American Geographical Society, *World Atlas of Epidemic Diseases* (edited by Prof. Dr. E. Rodenwaldt, Heidelberg), a book series on *Global Epidemiology*, *A Geography of Diseases and Sanitation* (Simmons, Whayne, Anderson and Horack), and other editions.

## INCESSANT CIRCULATION OF THE PATHOGENIC AGENT AS BASIS FOR THE CONTINUANCE OF A NATURAL FOCUS OF DISEASE

It has already been stated above that *the continuity of circulation of a transmissible disease agent in its natural focus is the basic factor determining the very existence (and duration) of this focus.* But for all its continuity, the circulation process is divided into basic steps in each of its tours or cycles; it is their chainlike, "spiral" change (Pavlovsky, 1963) that sustains the existence of a disease focus in nature. The character of these steps should be considered with regard to the pathogenic agent passing through the entire route of this circulation (even if passively).

These steps are as follows: (1) the very act of infecting an animal with a pathogenic agent; (2) the term of presence of the pathogenic agent in the blood stream of a donor body (virusemia, bacteremia) in quantities sufficient for infecting a new vector; (3) the conditions under which an infected animal becomes a disease donor; (4) the entry of the pathogenic agent into the vector body; (5) the acquisition of an infective power by the latter; (6) the biting of a recipient by the infective vector; (7) the infection and disease of the recipient, as well as (8) *the latter's conversion into a donor for the next tour in the circulation of the pathogenic agent.* It should be added that the agents of certain diseases may, in the course of their circulation, be discharged into the external environment and retain their virulence there.

In each stage of such circulation, its basic steps are subject to the influence of environmental factors which, acting in combination, determine one sort of weather or another; a general influence is exerted by the microclimate in the biotopes of the vectors inhabiting a particular locality. Also important is the time required for the pathogenic agent to multiply within the vector body, or speaking in general, for the pathogenic agent to attain the point of exit from the vector. The latter is a poikilothermic organism; therefore the processes occurring within it are subject to a more direct influence by the environmental temperature than the corresponding processes taking place in warm-blooded animals; in the latter the influence of environmental factors on the course of the internal processes is modified by the functional activity of the body.

The very same external environment with its changing conditions influences the behaviour, in particular the aggressiveness of an infective vector with regard to an infection recipient, the latter's infection with a disease, and the subsequent conversion of the recipient into a donor.

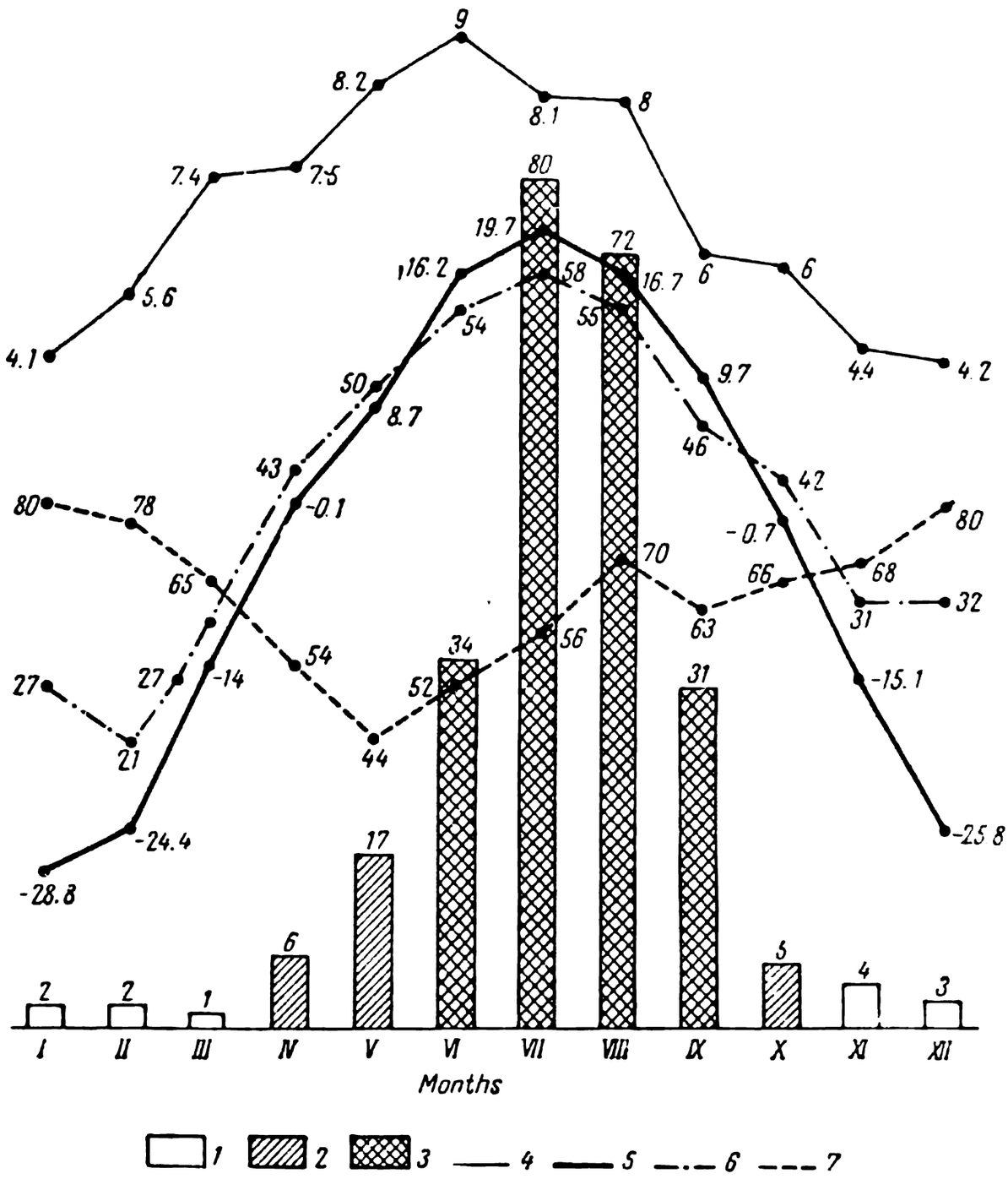
All this taken together makes up an intricate tangle of circumstances which it is necessary to clarify both in case of a disease with natural focus and in case of different geographical landscape belts characterized by specific diseases with natural foci, taking into account the influence of the microclimate and climate in its annual change.

It is clear that the study of natural foci in these respects is, in effect, a problem of ecological character; the problem of the ecology of certain diseases was also approached by foreign authors, such as Audy and others.

It is also understandable that with the present variety of known diseases with natural foci and continuing discovery of new foci, to say nothing of the tremendous size of the areas where such foci are found, the literature contains quite inadequate data on the circulation of pathogenic agents in their natural foci.

As an example we can use more detailed data illustrating the importance of climate as an active factor in the epidemiology and epizootiology of plague. It is so great that it determines above all the very development of plague epizootics. This problem was investigated with regard to the south-eastern Trans-Baikal region by N. V. Nekipelov (1957).

The Trans-Baikal region is a steppe zone where, as is the case in the steppes in general, rainfall is of decisive importance, since its scarcity (usual rainfall is not above 300 mm a year there) inhibits the growth of arboraceous plants; this circumstance in its subsequent chain connection affects also the local fauna. Rainfall may vary in the large in different years, though. For instance, at Borze a rainfall of 171.8 mm was observed in 1944, and 455.2 mm in 1953 (Fig. 73) (Nekipelov, 1957).




F i g. 73. Mean annual indices of the steppe climate in the south-eastern Trans-Baikal region according to observations at Borze. From evidence by N. V. Nekipelov (1957).

*1*—precipitation in the form of snow, mm; *2*—precipitation in the form of rain and snow, mm; *3*—precipitation in the form of rain, mm; *4*—duration of sunshine, hrs; *5*—mean monthly temperatures; *6*—cloudiness, per cent (according to Shestakovich); *7*—relative humidity, per cent.

As the author of the present book witnessed himself, the year 1938 was extremely droughty in the Khabarovsk territory, whereas in the next year 1939 there were many rains, particularly in the area of the "Krivoi Klyuch" research station of the U.S.S.R. Academy of Sciences located in a mountainous taiga district outside of Ussuriisk, in which barely 10 to 12 days passed without a rain during the entire summer season.

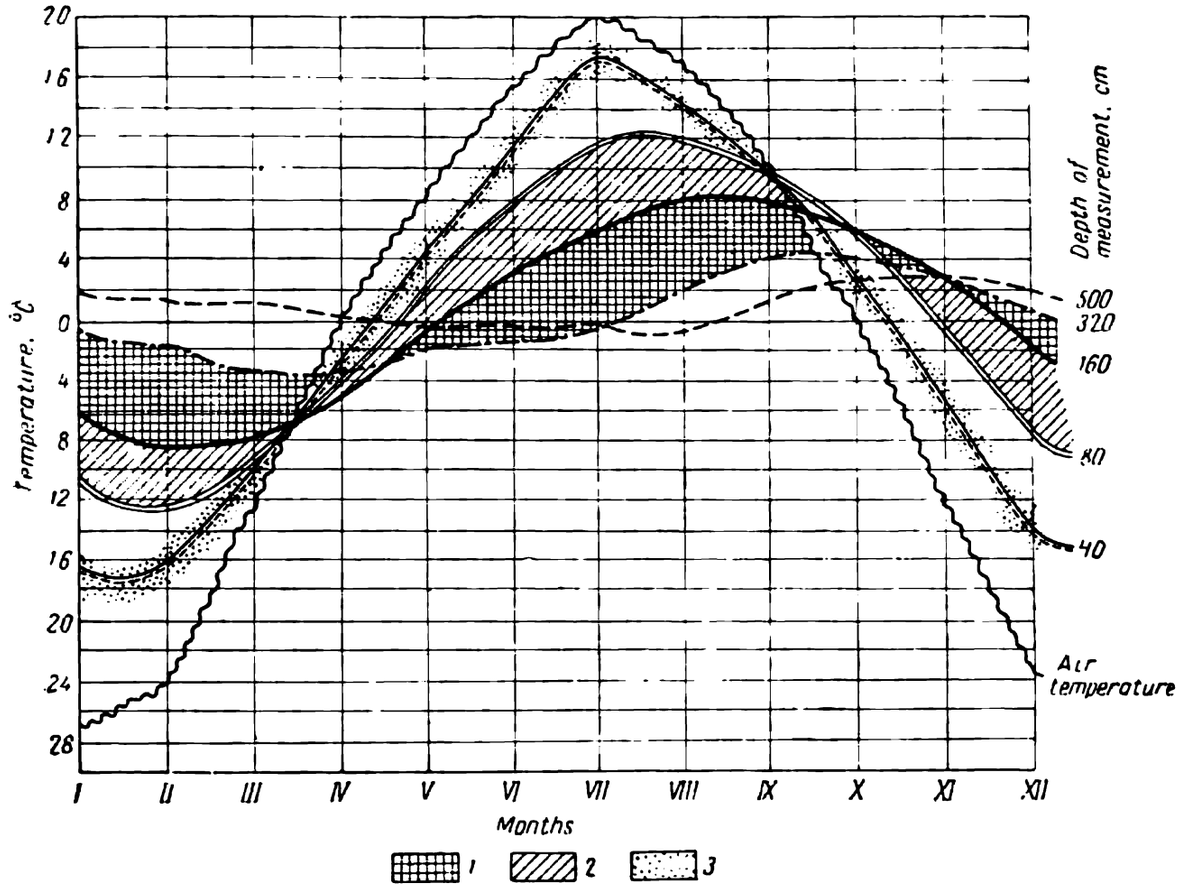
Scarce rainfall leads to formation of deserts, and in the Trans-Baikal region the desert-like steppe is the principal habitat of Brandt's vole; the Mongolian gerbil has also been infesting the steppe in growing numbers during the past few years. Winter snowfall is very scanty here (only from 4.5 to 5-6 per cent of the total annual rainfall). Therefore, the snow cover is blown off into ravines and narrow depressions in the ground by winds which are a constant occurrence in the steppes. The bare land freezes through to a great depth. As a matter of fact, the coat of snow begins to disappear as early as March; in the steppe it keeps not longer than 5 months a year.

In the forest steppe the snow covering, although shallow, keeps longer and is of a more permanent character. Winter precipitation in the forest steppe is twice as large as in the steppe regions on the average.

All this influences the fauna also: in the steppe the blue hare which turns white in winter and the ermine are rarely found, whereas in the forest steppe they are frequent. In the steppe, the Tolai hare which turns gray in winter is common, whereas in the forest steppe it is found infrequently. The Djungar hamster which turns white in winter retains its summertime colour in the snowless steppes of the Trans-Baikal area even in winter.

The most rainy period in the the Trans-Baikal area is July and August. In the Trans-Baikal steppes, rainstorms occur when water is so profuse that the soil, however dry, cannot fully absorb it. It floods rodent burrows, and their hosts are drowned en masse. Even in the months with heaviest rainfall there are usually dry spells of 7 to 9 days, whereas summer droughts may last as long as 17 days.

The climate here is on the whole continental; the air temperature declining to 50°C below zero in winter and soaring to 40°C above zero in summer. The range of annual temperature fluctuations is wide which inevitably affects the physiological characteristics of various species of mammals, including rodents (Kalabukhov and Ladygina, 1953). For example, in the coldest months of a severe winter, non-hibernating rodents cease to come upon the ground surface. At this time, Brandt's voles and gerbils shut the entrance to their burrows with earth, while terrestrial carnivores, such as polecats, keep to their burrows for a week and avoid coming onto the snow-covered ground surface.




F i g. 74. Changes of mean monthly temperatures in the soil at different depths in burrows of tarabagans (*1*), Daura suslik and jerboas (*2*), pikas, gerbils and field voles (*3*). According to N. V. Nekipelov (1957).

Rodents spend much time within their burrows, where they are influenced by the temperature and humidity of the soil, which are more stable than those on the earth surface at a given time and depend on the depth of the burrow (Fig. 74); (Nekipelov, 1957). As far back as 1932, Y. P. Vlasov showed that in the Kara Kum desert and in the Trans-Baikal area the diurnal range of temperature fluctuations on the soil surface reached 30 degrees on some days, whereas in a burrow, at a depth of 40 cm, it varied within the limits of only one degree. In one study in 1951 the difference between the temperature at a depth of 20 cm and that on the surface was two-three degrees. It will be recalled that the majority of mouse-like rodents and pikas in the steppes make burrows of from 20 to 50 cm in depth. Even such a small depth of burrow as 20 cm delays the onset of maximum diurnal temperature; at a depth of 1.5-2 m the annual temperature is constant.

The temperature in the burrow differs by only one-two degrees from that of the surrounding soil (Nekipelov, 1936). This temperature is near to that of the nest walls, whereas in the bedding of a nest occupied by assembled rodents the temperature is much higher and is close to that of their bodies.

Consequently, in case of the soil freezing to a greater depth, hibernating animals are exposed to a lower temperature. The depth of burrows varies with different rodent species. With smaller mouse-like rodents it is usually not more than 40 cm, with jerboas and susliks 50-100 cm, rarer 150 cm and more, and with marmots from 1.5 to 4 metres (Letov, 1950).

The expenditure of fat built up by a marmot towards winter depends on the environmental temperature and grows substantially when it declines to from 0 to 5°C, the body temperature of the marmot itself falling to 2°C. At an environmental temperature of 5-6°C the marmot's dormancy is at its height, its own body temperature declining to 8°C (Leshkovich, 1950). A hibernating marmot needs its fat reserves also for getting over the time of food scarcity in spring. Marmots have developed a habit for building a spacious nest chamber up to 1-1.5 metres in diameter, in which the bedding is just as large. Marmots hibernate in groups of several individuals, which helps maintain the temperature in the burrow at 8°C from January through March (Ryabov, 1948).

The microclimate (air temperature and humidity) affects not only the rodent itself (i.e., its metabolism) but also its external parasites.

The degree of air humidity influences the growth of grass, facilitating or retarding its drying, which in turn has a bearing on the state of rodent feed reserves.

The least air humidity in the steppe itself is observed in April, May and June. Moreover, the growth and drying of grass and parchment of the soil are influenced by the combination of the humidity and force of winds. In the steppe winds, as has been said above, are common and sometimes as strong as to prevent the use of powdered pesticides. This takes place in April and May, sometimes in March and in summer, until October. Winds attain the greatest force in the midday, while at night it is nearly always calm, just as in winter.

On the whole, however, an aggregate of factors is at work, which can be estimated from the meteorological observations at Borze.

It has to be known how the aggregate of climatic and microclimatic factors influences the development of plague epizootics and plague in man. The cause of plague among humans was their frequent contact with steppe animals when hunting tarabagans (Trans-Baikal marmots). The use of snares for trapping them, especially along railroad lines, had markedly reduced their number even before the time when the plague control organization took direct measures to wipe out tarabagans. This resulted in the assanation of a large area. No directly proportional relation has been established between the number of plague cases and the size of the area hit by plague epizootics.

After the advent of Soviet power greater care was displayed in detecting plague epizootics and plague cases among humans, as

distinct from the pre-revolutionary times when public health had been given inadequate attention and not all fatal cases of plague had been identified with accuracy. The infection of humans is in the final analysis determined by social factors. But what happens in natural foci? V. V. Kucheruk (1945) noted a connection between the development of plague epizootics and a mass infestation by Brandt's field voles, which was facilitated by droughty periods. In such years, feed stock (edible parts of plants collected by Brandt's field voles) is better preserved within burrows. Grass is scanty in such years, so contact is more likely between rodents searching for food; in a droughty autumn tarabagans build up less fat which adversely affects their fecundity in the next spring (Nekipelov, 1955) and increases their susceptibility to plague infection, as has been shown in experiments by E. I. Klets, V. P. Khrustselevsky, and other workers (1955).

The number of rodents is a highly important factor. In dry years, the number and the area of habitat of Brandt's voles grow, but with the return of the usual climatic conditions they become extinct in the newly-occupied areas in a few years' time. In humid years, however, there is an increase in the number and areas of habitat of the social, eastern and Ungur voles. Nekipelov notes that in years of mass infestation by Brandt's voles plague epizootics were observed in places where these rodents were totally absent. Hence his conclusion that mass infestation by Brandt's voles and plague epizootics occur in consequence of the action of some general ecological factors.

An increase in tarabagan populations in a given year is undoubtedly largely dependent on the conditions of fat accumulation during the preceding autumn with all the ensuing consequences which have been noted above (Nekipelov, 1957).

## THE AREA OF A TRANSMISSIBLE DISEASE. PLACES OF INFECTION AND DISEASE. LOCALIZATION OF NATURAL FOCI OF DISEASES AS A GENUINE FEATURE OF NOSOGEOGRAPHY

An important epidemiological feature of a transmissible disease with natural foci is the character of the places where *man is likely to contract it*: this usually occurs where infective vectors are prone to bite man, i.e., in the area of a geographical landscape with natural foci of this disease.

Medical statisticians recording transmissible diseases determine *the number of applicants given medical assistance* at the hospitals of a given locality, and the data collected are used to draw up special charts. Yet they fail to illustrate always the *true* distribution of transmissible diseases, particularly those with a prolonged incubation period, during which an infected subject may move to another,

remote place where this disease is absent and be registered there as a case of such on account of its manifestations.

The area of transmissible diseases spread by specific vectors is determined by the latter's zoogeographical distribution, yet within the limits of the habitat of a specific vector cases of the disease spread by it will not be necessarily met with in any point. For example, the fauna of the Crimean Peninsula includes *Phlebotomus papatasii*, the vector of cutaneous leishmaniasis, but this disease is nevertheless absent in the Crimea.

This suggests the conclusion that the true (natural) features of the geographical distribution (nosogeography) of transmissible diseases associated with their specific natural foci are determined precisely by the latter's localization.

CHAPTER VII

# LANDSCAPE EPIDEMIOLOGY OF ZOOANTHROPONOSES

## OLD AND NEW DISEASES WITH NATURAL FOCI

A reliable detection of natural foci of transmissible diseases requires first and foremost complex zoological, parasitological and microbiological investigations. These are necessary for the study of new diseases, particularly in new, uncultivated regions. If such a new disease is known to have occurred in humans or cases (sometimes outbreaks) of it are believed to be due to the sufferers' stay in parts of certain territories, clinicians, epidemiologists and other specialists should be enlisted for a complex research. As has been shown by experience, a number of ostensibly new diseases discovered in Soviet territory proved novel only to medical practitioners who have but recently learnt to identify them with accuracy. In fact, they had existed since long ago in this territory but were not regarded as independent nosological units by medical practitioners, so they were lumped together under a general diagnostic name or called otherwise or remained totally unknown to medical science. This had been the case, for example, with tick-bite fever (Marseilles fever, Mediterranean typhus fever) until its presence was established also in Soviet territory.

The same happened to tick-borne encephalitis which proved to be similar to Kozhevnikov's epilepsy. It was found by retrospective diagnosis that this disease had not been brought from the outside (for instance, into a virgin taiga) but had existed earlier as evidenced by persons who had sustained it 20-30 years before.

For a practical, quick estimation of possible epidemiological hazards in any area suspected as having latent natural foci of disease any evidence of their presence is important. The first step to collect such evidence is to search for possible vectors of a given disease and determine their spontaneous infection with its agent. But this takes time and requires a minimum complex study, therefore, importance is attached to a general preliminary estimation of the

health hazards in a locality presumed to have natural foci of transmissible diseases. This is based on a general survey of its geographical features (landscape epidemiology of zooanthroponoses) with regard to those diseases with natural foci which have been more or less adequately studied. But life is never at a standstill, so sometimes it is necessary to make an immediate or at least a tentative and conventional estimation of a landscape for the suspected presence of natural foci of diseases, with an eye to taking whatever prophylactic measures may prove feasible in the early period of life and work in a new territory. The first step should be to determine the character of the geographical landscape with regard to the possible presence of natural foci of zooanthroponoses, inasmuch as such connection has been found to exist in other localities and may be referred to the territory subject to survey. Cases of tick-borne encephalitis, for example, are encountered among timbermen and other workers travelling deep into *the broad-leaved taiga*; tick-borne rickettsiosis is contracted by man in *the steppe zone*, the rural form of cutaneous leishmaniasis in *the semi-desert zone*, tick-borne spirochetosis in *the southern mountainous zone*, etc.

Thus, the epidemiological significance of a locality is determined by the following factors:

(a) the landscape of *an area* with natural foci of diseases in newly-settled and reclaimed regions (the taiga, steppes, virgin lands, etc.);

(b) the extent and nature of contact between man and his natural environment.

## LANDSCAPE ZONES IN SOVIET TERRITORY

In the direction from north to south Soviet territory is subdivided into the following landscape zones: *the tundra*, *the forest-tundra*, *the taiga* (with broad-leaved and coniferous forests), *leaf-bearing forests*, *the forest-steppes*, *the steppes*, *the semi-deserts*, *the deserts*; a limited area in the south is occupied by *subtropical* and *tropical forests of deciduous trees*.

Landscapes and their characteristic habitats are considered not only in regard to their horizontal (latitudinal) but also their vertical zonation physically measured by their elevation above sea level. A step-like change is characteristic also of the latitudinal landscape zones which follow one another; the nearer to the south, the higher the lower boundary of a landscape zone. For example, the tundra proper and the taiga zone at a certain height above sea level are covered by *the mountainous tundra* known as "*goltsy*" (corrupted Russian word meaning "naked"). In the tundra belt, it begins almost at the base of the hills, whereas in more southerly interior regions, for example, in the Altai highland, the lower boundary of the mountainous tundra at places lies at an altitude of 2,300 m above sea

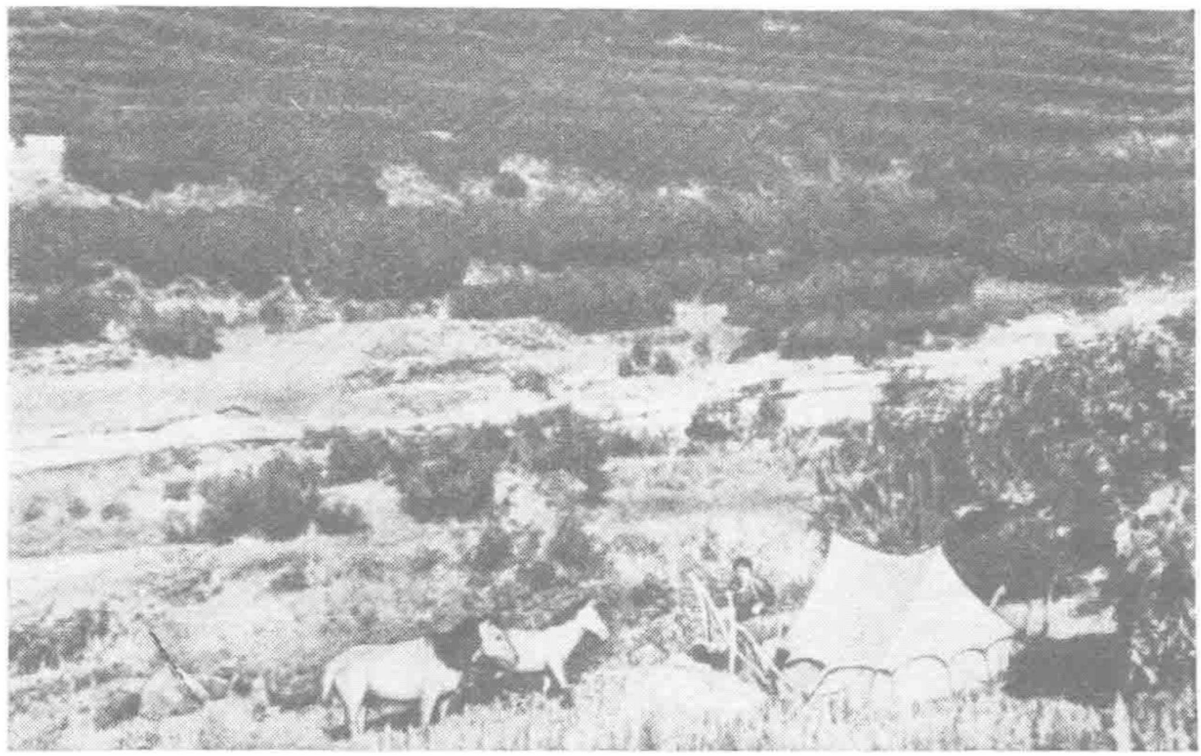


Fig. 75. Growths of cedar and alder creepers. Eastern Kamchatka. Photo by Y. Averin.

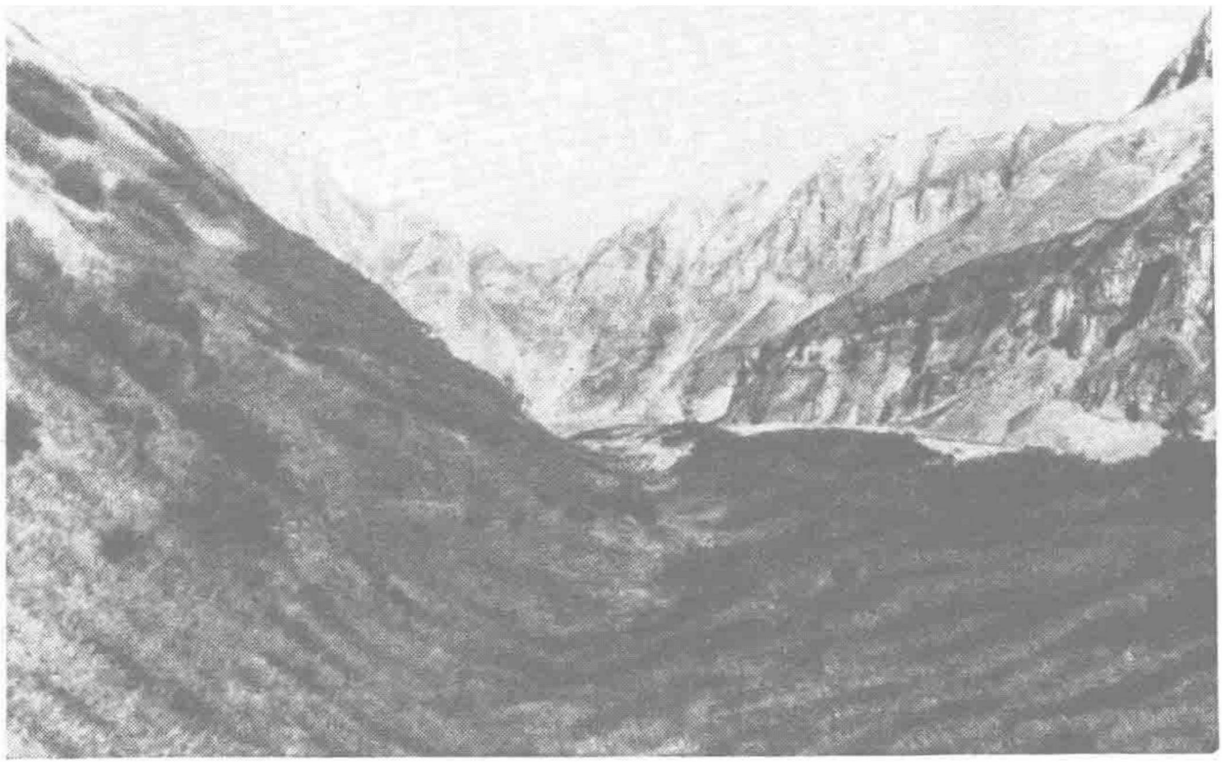


Fig. 76. A complex of stations in the Yelizov district of the Kamchatka Peninsula: Alpine fields, growths of cedar creepers and rocks. Photo by A. I. Kurentsov.

level, which is the southernmost occurrence of "goltsy". No grass turf forms here.

The lower bounds of the "goltsy" are overgrown with dwarf trees and scrub. At different meridians the leading elements of this vegetation are as follows: from the Murman Coast to the Urals—the birch; in the Urals—the larch and even spruce, in Western Siberia—the larch, in Eastern Siberia—the cedar creeper (see Figs. 75, 76), alternating with tracts of lichen tundra.

In the mountains of the U.S.S.R. the following belts are prominent, counting from above downwards: the mountainous tundra and Alpine meadows, the mountainous mixed forests of coniferous and broad-leaved trees and broad-leaved forests, Alpine, highland and foothill steppes and deserts.

This generalized division into landscape zones has been made by Prof. V. B. Sochava at the author's request to replace the highly detailed geobotanical map of the U.S.S.R. divided into zones for botanical purposes. This map was drawn up on a 1 : 4,000,000 scale under the editorship of E. M. Lavrenko and V. B. Sochava in 1954 and supplemented with a two-volumed manual *Vegetation of the U.S.S.R.* (1956).

L. S. Berg gave much attention to the study of the physicogeographical (landscape) zones of the U.S.S.R. (1936, 1947, 1952). He classified them as follows (1952):

The tundra zone.
The forest zone.
    The taiga subzone.
    The mixed forests subzone.
The broad-leaved forests of the Far East
    (The Amur river basin).
The forest-steppes (according to L. S. Berg).
The mixed zone.
The semi-desert zone.
The desert zone with a temperate climate.
The Central Asian mountains.
The subtropical zone

The following zones were specially singled out:

The Caucasian Mountains.
The Crimean Mountains.
The Eastern Carpathian Mountains.
The Ural Mountain Range.
The Altai Mountains.
The Sayany Mountains.
The territory of what is now the Tuvinian Autonomous Republic.
The Baikal and Trans-Baikal regions.
The mountains in North-Eastern Siberia.
The mountains in the Amur river basin.

The Sakhalin Island.
The Kuriles.
The Kamchatka Peninsula.
The Arctic mountains.

L. S. Berg defined the geographical landscape as "*an aggregate* or group of objects and phenomena in which the features of the relief, climate, water, soil, vegetation and animal life... merge into one harmonious whole typically recurring over the extent of a given Earth zone" (Berg, 1947, p. 5). In each landscape region its elements are adapted to and reciprocally influence one another. Since the appearance of man, the geographical landscapes have been exposed to his modifying influence in one form or another; therefore, it is highly important to preserve intact some parts of virgin areas, i.e., regions which have never been and should not be modified by human activities. Such parts of virgin land of any kind whatsoever would be a museum of living nature, as it were; a detailed study and scientific approach to it would be improved with the progress of science and emergence of new problems, which would give a clearer idea, in the comparative aspect, of man's modifying influence on nature. It has been and is differently manifested in various parts of one and the same zone, and man should strive to become capable of a rational control of natural phenomena and the development of the organic world as an inexhaustible source of physical resources necessary for human society.

In Soviet territory landscape zones have since time immemorial been influenced by human activity which has changed or is changing the nature of various localities. In the historical past this was extensive destruction of forests to reclaim areas for crop farming, and today it is the creation of inland water reservoirs as the man-made fresh-water seas, the construction of long irrigation canals, like the Volga-Don Canal, the Turkmenian Canal, the irrigation systems in the North Caucasus, to mention but a few. This modifying influence of man on nature takes place on a tremendous scale but many important changes are caused by minor measures taken on a limited scale, which entail substantial local consequences.

From the viewpoint of medicine as well as veterinary medicine and fur-farming (stockbreeding) special importance should be attached to finding out the presence in different landscape zones of pathobiogeocoenoses whose members include agents of virus and bacterial diseases, rickettsiosis, spirochetosis, as well as mycosis, protozoiasis, helminthiasis, acarinosis and entomiasis. Many of the agents of the above diseases may be present also in the external environment from which they can gain access to man and animals. Other pathogenic agents, however, *in the present stage of evolution are never found in the external environment and always habitate exclusively in a living organism* from which they gain access to man and

farm animals by one route or another. It is the biogeocoenoses joined by disease-producing agents that natural foci of certain diseases associated with a particular landscape zone correspond to.

The finding out of this relationship, discovery of the conditions, and determination of the place and time in which infection with agents of diseases with natural foci may take place dictate the need for an analysis of the biocoenotic relationships between the members of a particular biocoenosis. These relationships determine the duration of natural disease foci, their existence in a latent state and as relicts, their fate in the process of developing a given territory, their extension towards places inhabited by man and, conversely, the possibility of their return from civilized surroundings back to nature, the appearance of secondary temporary or permanent foci, etc.

## RELATIONSHIPS OF NATURAL FOCI OF DISEASES TO GEOGRAPHICAL LANDSCAPES

At the present time it is already possible to draw up a chart of latitudinal relationships of natural foci of diseases to the geographical landscapes of the U.S.S.R.

The Soviet Union occupies one sixth of the Earth's land area. In view of the variety of terrain features, climate, and the character of economic activities, such a vast territory cannot be rapidly explored in detail with regard to the geographical distribution of natural foci although this is the subject of study carried by special research centres and many departmental institutions, as well as a network of special plague-, tularemia-control and other centres.

Nevertheless, the general features of the landscape epidemiology of zooanthroponoses can be outlined.

In the islands lying to the north of the Siberian coast there occurs rabies of polar foxes and, as a secondary phenomenon, rabies of reindeer.

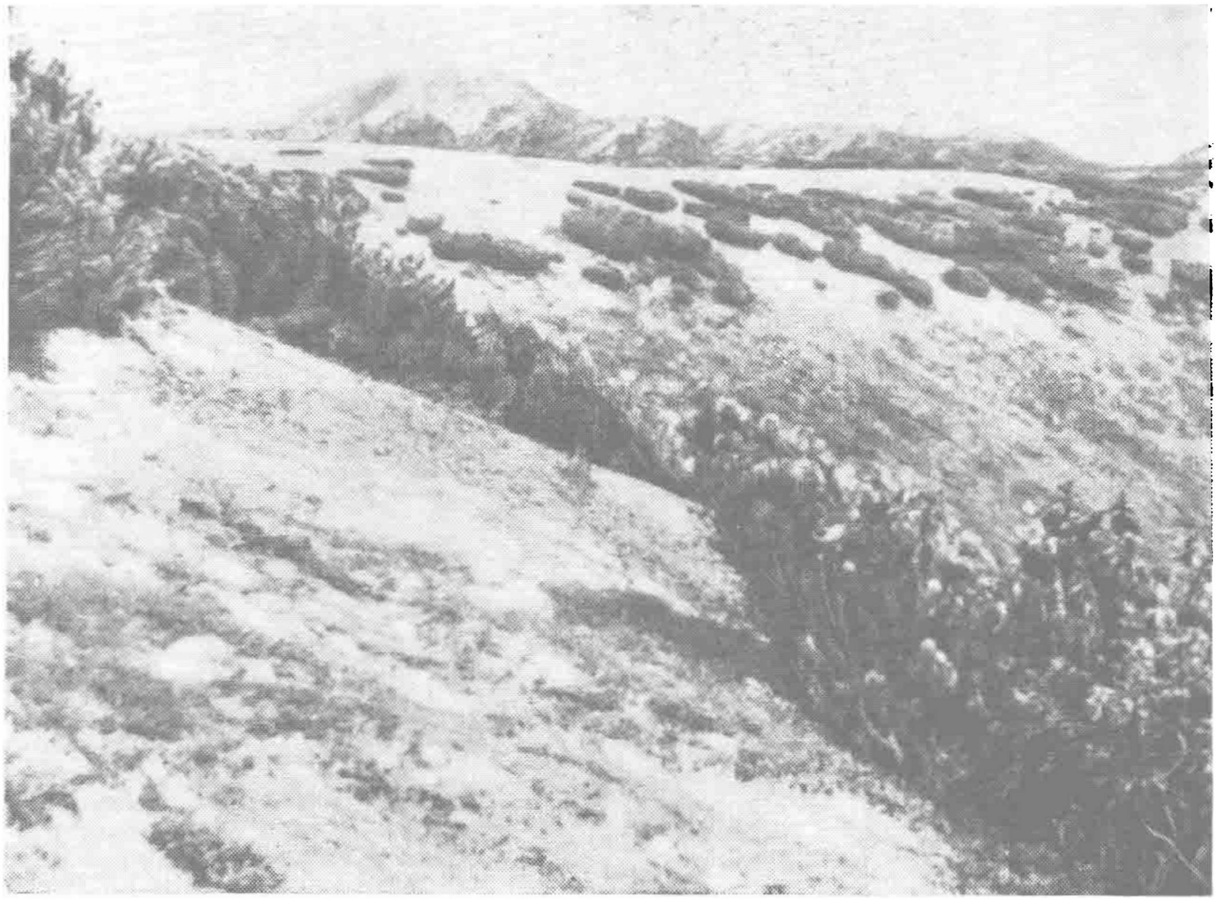
The tundra zone (Figs. 77, 78) is seasonally infested by punkies.

In connection with the discovery of many arborviruses transmitted by *Culicini* mosquitoes, the problem of the health hazards due to punkies, which make certain territories difficult to live in, requires an approach other than that based exclusively on their estimation in respect of the toxic effects produced by the bites of these winged bloodsucking dipterans.

It is quite probable that mosquito species coinhabiting with the punkies may be found to include vectors of arborviruses pathogenic for man which have not yet been discovered in the northern areas of the U.S.S.R. Cases are known of spontaneous mass southwards migration of lemmings which may be carriers of *B. tularense* transmitted by mosquitoes or water-borne.

F i g. 77. The Lapland preserve. Seen in the background is the tundra; in the foreground is a lake cove, a site of massive hatching of punkies. Photo by O. I. Semyonov-Tian-Shansky.

F i g. 78. The highland tundra in the Koryak country. Photo by A. I. Kurentsov.



F i g. 79. The highland forest-tundra covering gentle slopes. The Koryak country. Photo by A. I. Kurentsov.

The tundra zone merges without any marked boundary into *the forest-tundra* (Fig. 79) distinguished by sparse tree growths and continuous with *the forest* (*taiga*) *zone* (Figs. 80-82), where one may encounter natural foci of rabies and more southwards those of tick-borne encephalitis, whose northernmost focus has been discovered at Narym.

*The coniferous taiga* without an admixture of broad-leaved trees, scrub and devoid of a grass covering and *the sparse taiga* are an unfavourable environment for *Ixodes* ticks—vectors of tick-borne encephalitis—and for their hosts.

The required environment is available in places with an admixture of *broad-leaved deciduous trees* (Fig. 83), thick scrub and undergrowth, and grass-covered soil, particularly in burnt-out (Fig. 84) and cleared spaces (Fig. 85), where the mammalian hosts of ticks are more numerous, and the thick litter of dry fallen leaves provides a more favourable microclimate for the free-living stages of ticks —for laying eggs, embryonal development, and for the pre-molting stages engorged with blood from their hosts at different phases of metamorphosis.

All these conditions become more favourable and the natural foci of tick-borne encephalitis more numerous somewhat farther

F i g. 80. Wind-fallen wood in the taiga of the Khabarovsk territory near the village of Obor. Habitat of rodents and ticks—vectors of the tick-borne encephalitis virus. Photo by E. N. Pavlovsky.

south, in the zone of *the cedar* and *broad-leaved taiga* of the Far East and the neighbouring regions.

Here tick-borne encephalitis foci exist even in the depth of the taiga where man has never set foot and where during its reclamation lumbermen, topographers, prospectors, road-builders, builders of various projects and newsettlers run the risks of entering regions with foci of tick-borne encephalitis. These have sprung up by evolution utterly irrespective of man and have existed since ancient times in connection with the formation of pathobiocoenoses.

Not any part of the taiga, however, is dangerous in the above respect. The boundaries of natural foci of tick-borne encephalitis remain diffuse, i.e., indistinctly outlined; indeed, it is hard to think of definite boundaries for the foci of prevalence of ticks

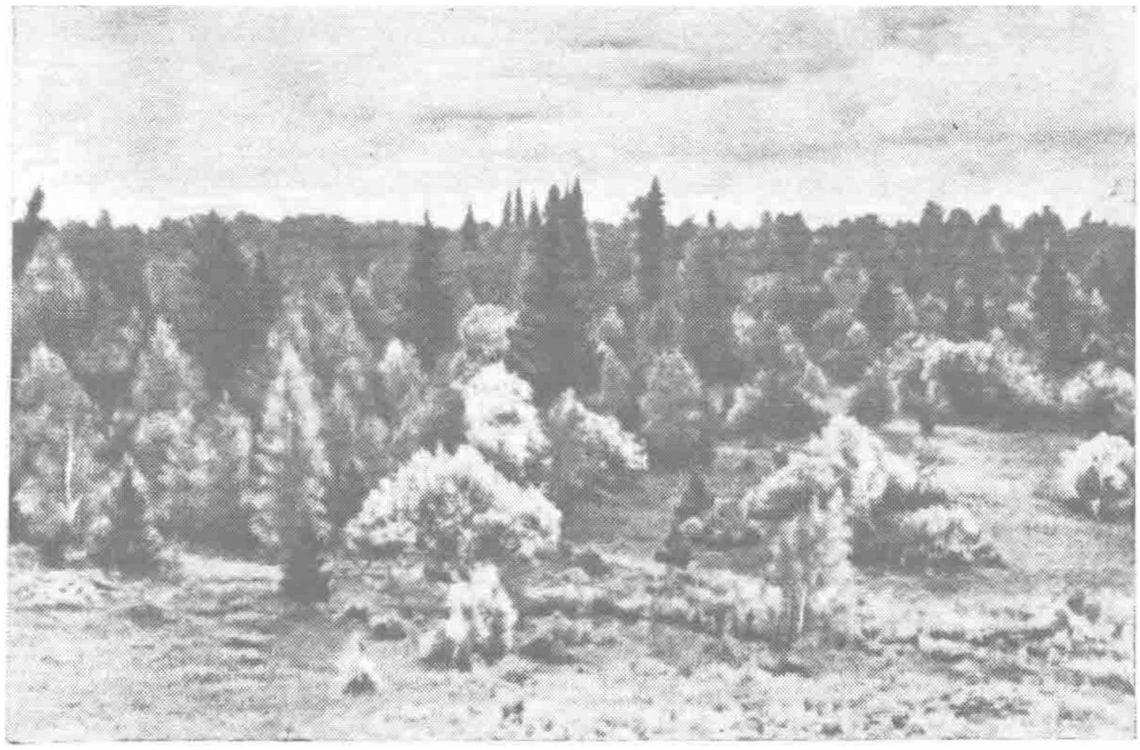


Fig. 81. A mixed forest beyond the River Kitat in the Andzhero-Sudzhensky district. A focus of tick-borne encephalitis. Photo by N. N. Gorchakovskaya.

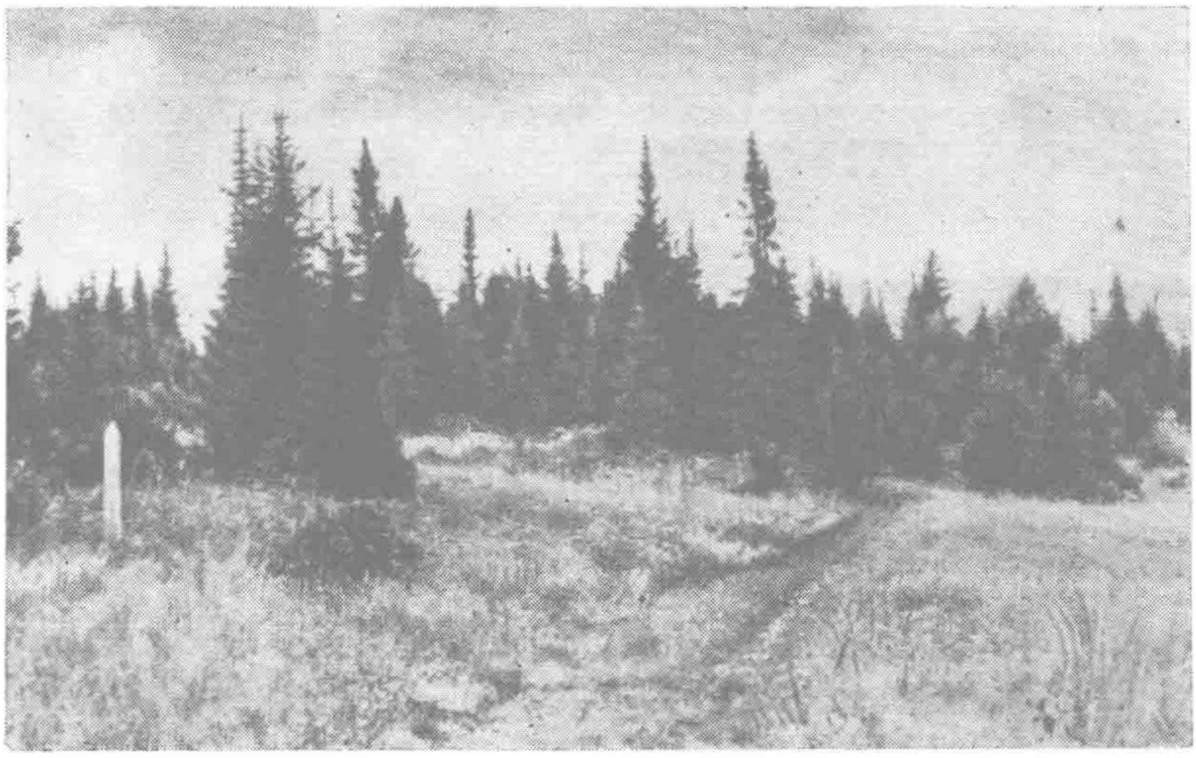
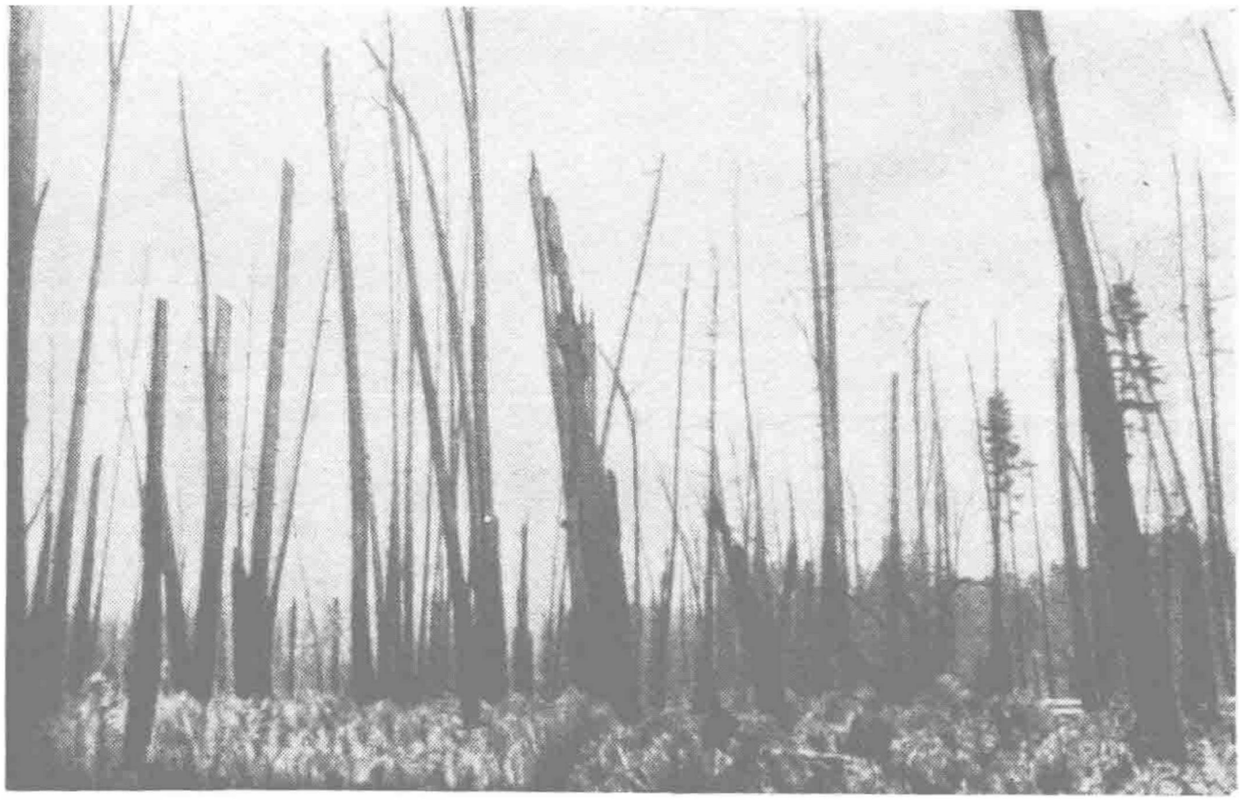


Fig. 82. A coniferous forest beyond the River Kitat, a focus of tick-borne encephalitis. Photo by N. N. Gorchakovskaya.

F i g. 83. The Suputin preserve. The taiga with an admixture of deciduous trees in its part under reclamation. A habitat of *Ixodes persulcatus*. Photo by E. N. Pavlovsky.

dwelling in the forest litter. The ticks populate it ununiformly, even despite their relatively low mobility. They have rather well developed olfactory receptors and, guided by their sense of smell, the hungry ticks gather on paths along which various taiga beasts go to their permanent watering places of variable types.

The quantitative estimation of tick prevalence in test sections of the taiga made by B. I. Pomerantsev and G. V. Serdyukova [1947 (1948)] showed ticks to be numerous exactly on the paths used by animals and man, whereas a short way off on both sides of a particular path they were considerably less in number or were absent altogether. Moreover, they were uniformly distributed along the length of the path; therefore it is unreasonable to use the term



F i g. 84. A view of the taiga after the burning of dry herbaceous plants and shrubs. Photo by N. A. Petrishcheva.

"microfoci" in this instance since no distinct boundaries exist between gatherings of hungry ticks sitting on grass blades or in the lower parts of shrubs in an expectant posture, i.e., with extended front legs on which one finds olfactory organs in the form of Haller's fossae.

*The mixed cedar and broad-leaved taiga and the broad-leaved forests* of the Far East harbour latent foci of tick-borne encephalitis.

The conditions under which natural foci of tick-borne encephalitis exist change with progress in reclamation of the taiga (Figs. 83, 85, 86), depending on the extent of this process. When thinning out or clearing tracts of forest land and building settlements on unstubbed land, livestock is put to graze on pastures overgrown with grass and scrub, where it becomes infested by ticks, the more so, as the number of small rodents, hosts of the younger stages of tick metamorphosis, increases also. The rodents are in their turn attracted by farm buildings (granaries, sheds, dwellings, and storehouses) as well as by new objects associated with man's agricultural work (vegetable gardens and crop fields—Fig. 87, stacks of hay and straw, herds of farm animals, domestic animals, etc.).

In forestland one may also encounter natural foci of other diseases whose agents are spread by vectors or in another way.

During our surveys in the Far East for tick-borne encephalitis foci we happened to find in forest clearings used as cattle pastures ticks of the following three genera: *Ixodes persulcatus* (taiga tick

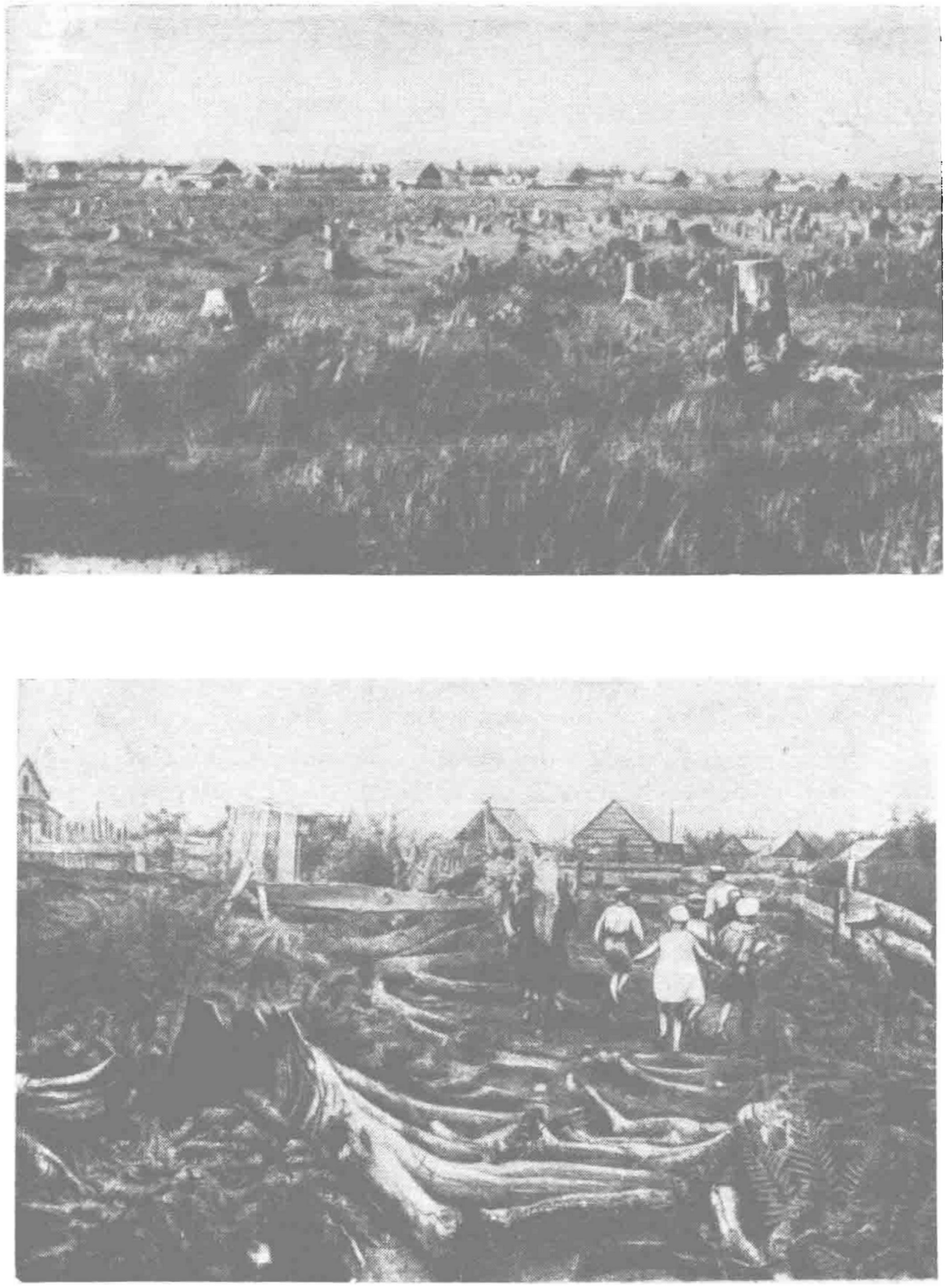


Fig. 85. A cleared space in the taiga (above) and a village laid out there (below). Photo by E. N. Pavlovsky.

Fig. 86. The settlement of Tayozhnoye of the Maritime Territory in a reclaimed space in the taiga. The residents have frequent contact with the taiga. Photo by Arkhipov.

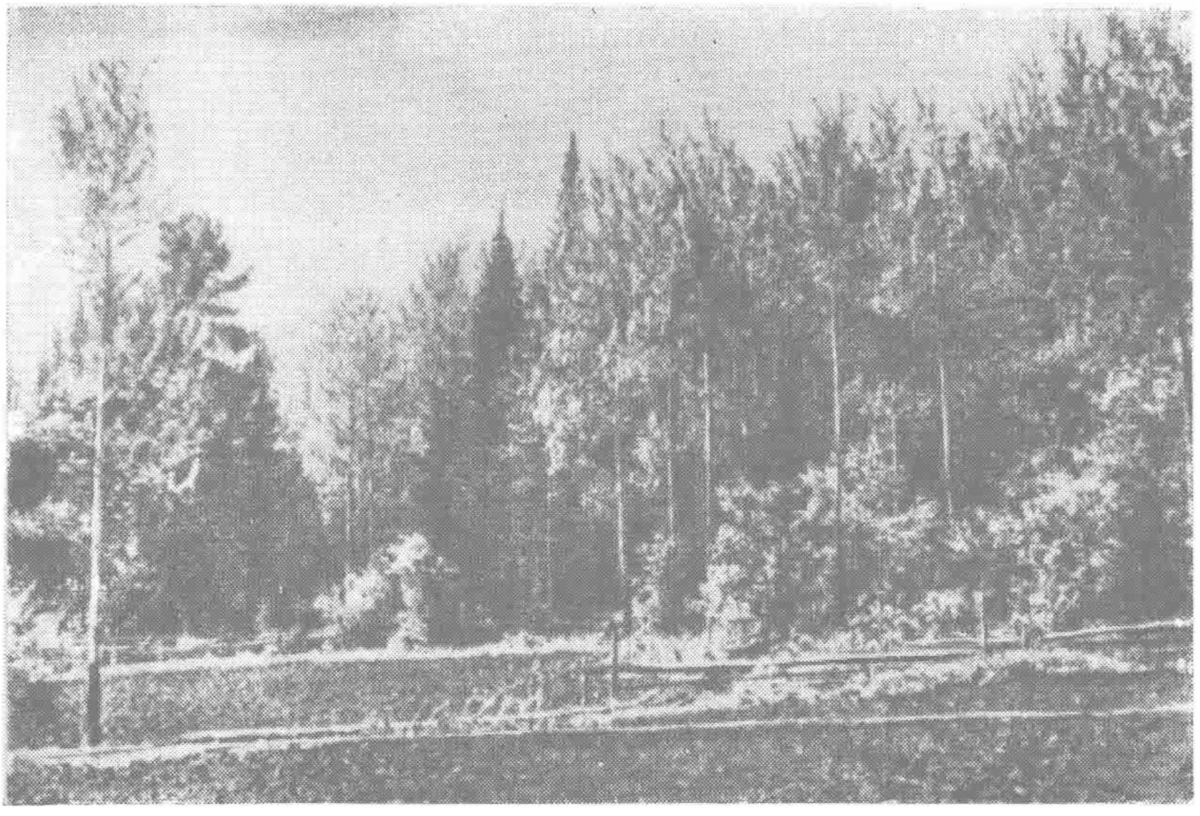


Fig. 87. Everyday contact with a focus of tick-borne encephalitis. Vegetable gardens at the edge of the forest. Kemerovo Region. Photo by N. N. Gorchakovskaya.

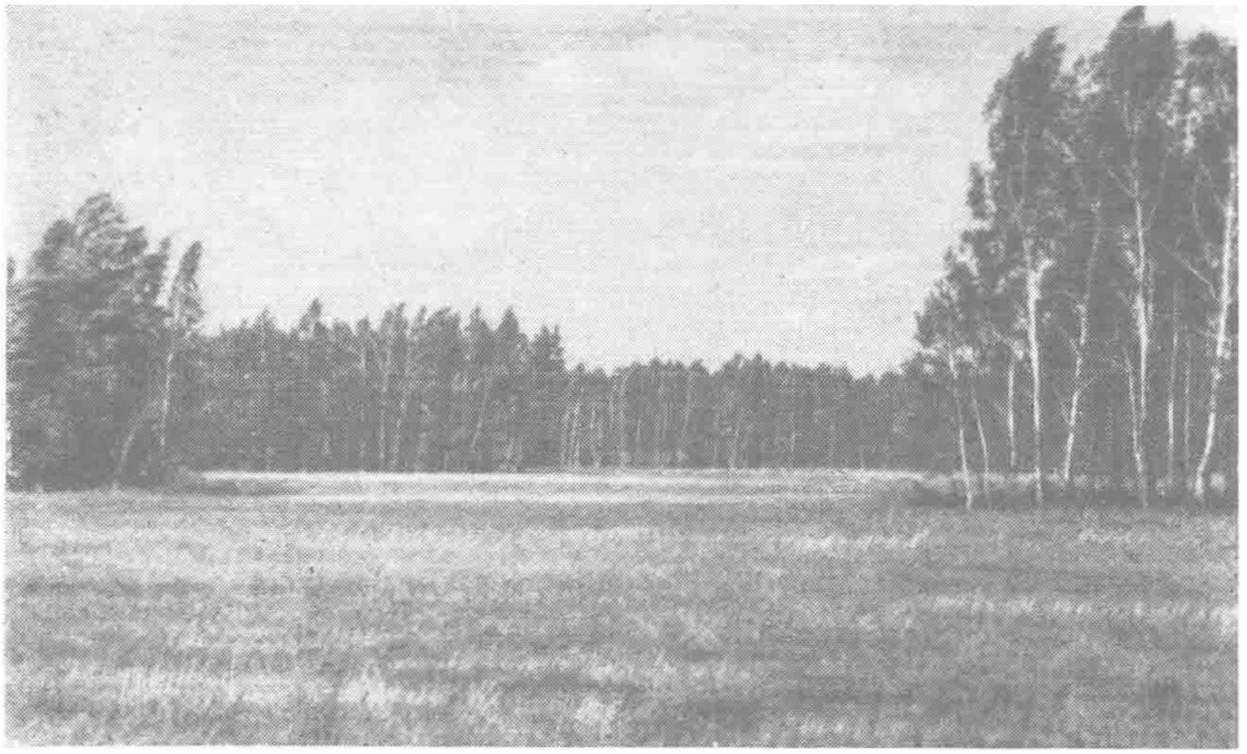
proper), *Haemaphysalis concinna* and *Dermacentor silvarum*. All of them proved capable of transmitting tick-borne encephalitis virus in experimental conditions, but the *Dermacentor* ticks are characteristic of steppe stations and gain access to the taiga with cattle brought there by man. In the taiga these ticks find a favourable environment in the open spaces of glades. It would be important to make sure whether the taiga has places with natural, indigenous populations of *Dermacentor silvarum* ticks other than those following in the steps of man. Ticks of the genus *Dermacentor* are a vehicle in the spread of tick-bite typhus rickettsiae in the Jewish autonomous region of Birobidzhan and, probably, in other regions of the Far East. Scrub typhus, an equivalent of Japanese River fever, is likely to be found in these places also. The prerequisites for this are known. These are the presence in the fauna of *Trombidiidae* ticks and possibly of a reservoir of *Microtus michnoi* rickettsiae, which are apparently equipollent in this respect to the Japanese *M. montebelloi*.

Towards the West, up the river Amur, *Dermacentor silvarum* ticks give place to *D. nuttalli* ticks prevalent also to the west of Lake Baikal in the Krasnoyarsk region. Here, natural foci of tick-bite fever are known to exist also towards the south; they were identified as late as 1938, two years after tick-borne rickettsiosis (Marseilles fever, or Mediterranean typhus fever) had been found by A. Y. Alymov in Sevastopol.

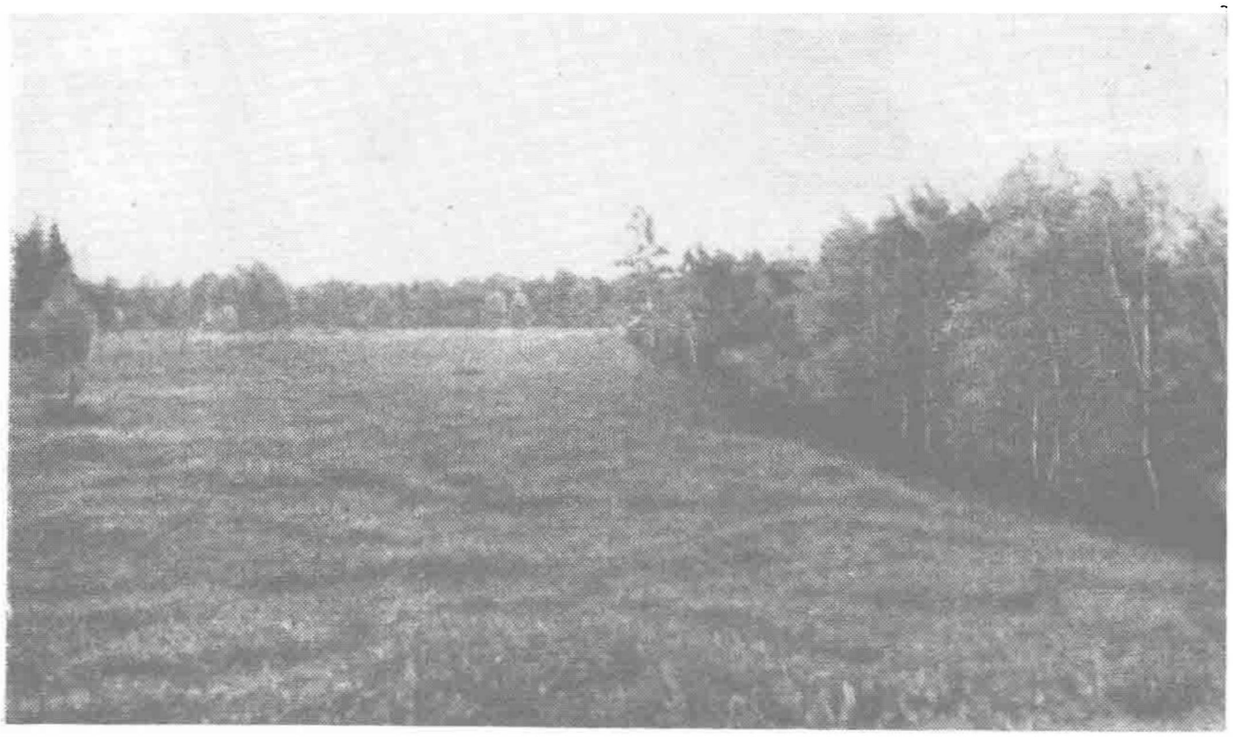
The possible occurrence of this disease in the U.S.S.R. was discussed in the textbook of medical parasitology (Pavlovsky, 1934, p. 355), and was corroborated by later evidence. Epidemiologically as well as for its course and outcome tick-borne fever is different from louse-borne typhus; in Krasnoyarsk, for example, cases of it were recorded among inhabitants of spring camps in the steppe. This disease, just as tick-borne encephalitis and others, proved to be of long standing in Soviet territory but new to medical men, who have only recently learnt to differentiate it from louse-borne typhus.

Through the Balkan Peninsula this "new" disease is connected with Mediterranean typhus fever encountered on the Mediterranean coast. Viewed in the large, there is a belt of prevalence of this rickettsiosis from Portugal and Morocco in the West to the Maritime Territory in the East of the Soviet Union. This belt is not without gaps, possibly because no surveys have been carried out in certain areas and because these diseases have not been observed or correctly identified in the desert, unpopulated or sparsely populated parts of this belt.

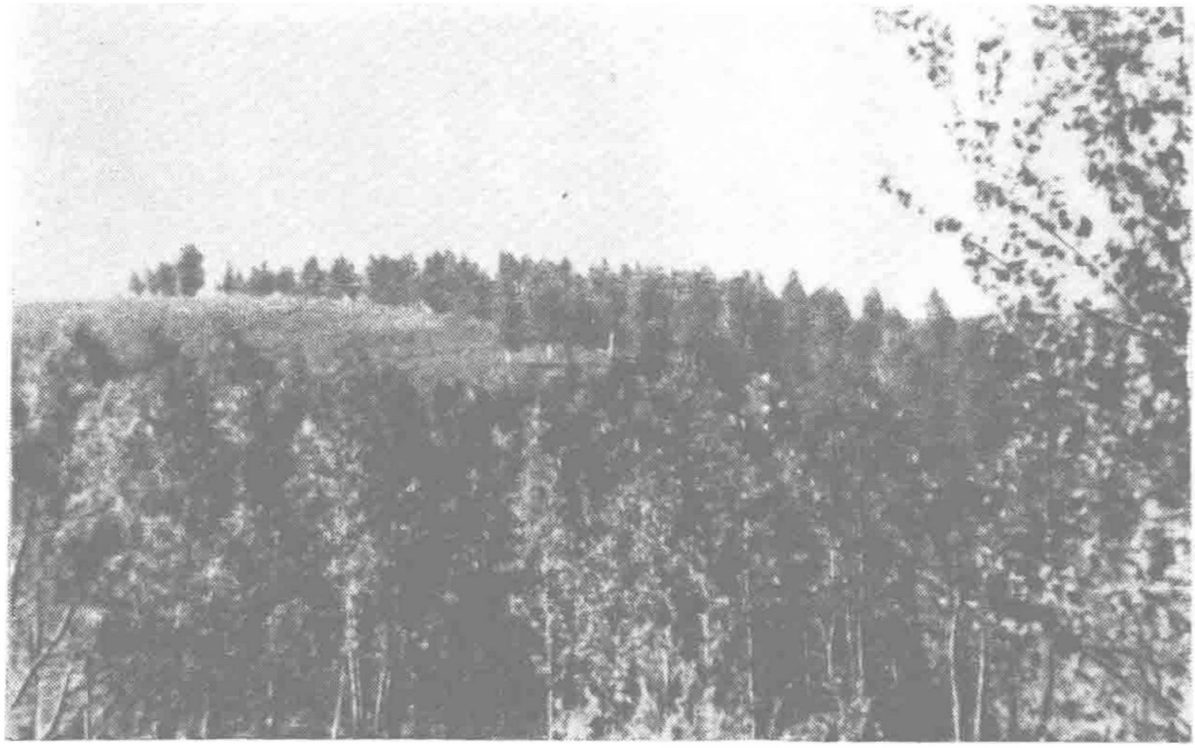
The vector of rickettsiosis in the Mediterranean and the Crimea is the southern canine tick, *Rhipicephalus sanguineus*, which has perfectly adapted itself to life in urban surroundings; farther to the east it is replaced by other vectors—*Dermacentor marginatus*, *D. pictus*, *D. nuttalli*, and *D. silvarum* ticks. This disease also occurs



F i g. 88. The forest-steppe in the Omsk Region. Growths of birch and aspen trees in the northern forest-steppe region. A habitat of the red field vole. Photo furnished by the Institute of Diseases with Natural Foci, Omsk.

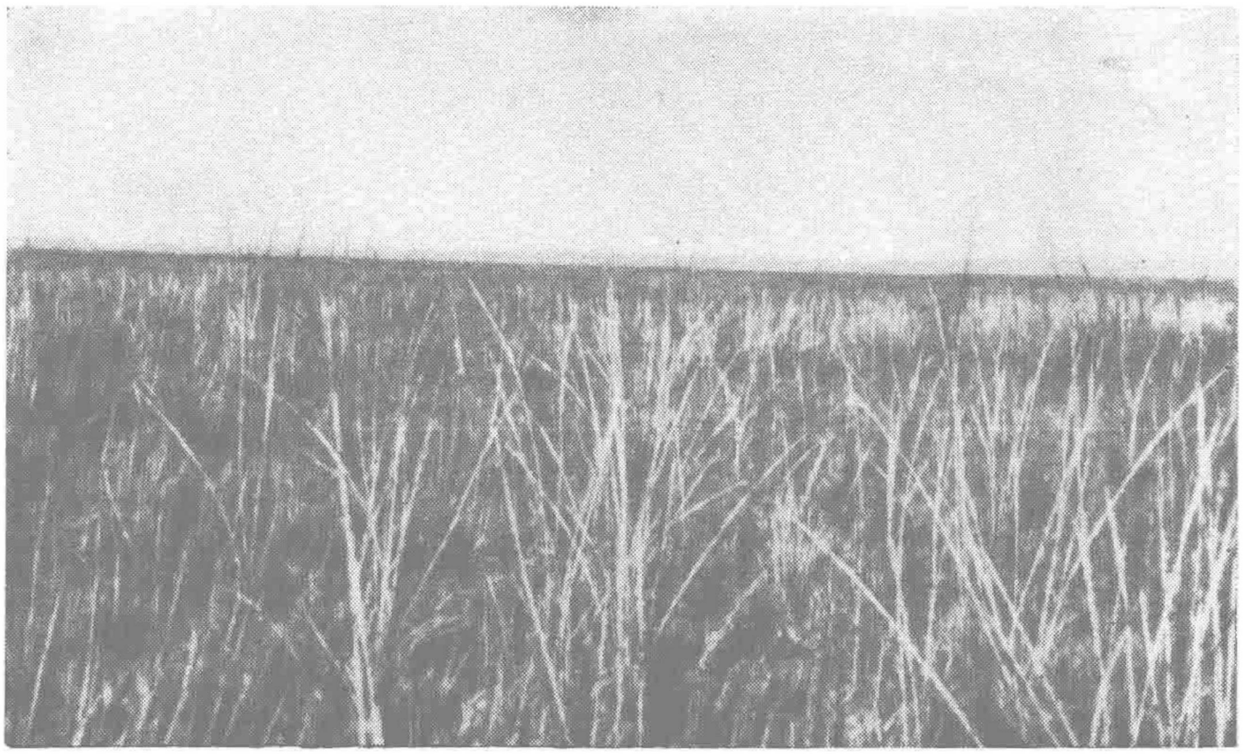


F i g. 89. Birch growths in the open forest-steppe.



F i g. 90. Birch growths on ravine slopes at the Toguchin section of survey work. Photo by the Institute of Diseases with Natural Foci, Omsk.

F i g. 91. The forest-steppe in the Omsk region. The northern forest-steppe region in the third decade of April. The time for the appearance of winterized hungry *Ixodes* ticks. Photo furnished by the Institute of Diseases with Natural Foci, Omsk.



F i g. 92. The steppe with natural foci of tick-borne fever transmitted by *Dermacentor nuttalli* ticks.

in Kirghizia and the Altai territory. It is transmitted by *D. nuttalli* ticks inhabiting the corn steppe, where man is also likely to contract the infection through their agency. The *Dermacentor* ticks have a characteristic biological trait. Their larvae and nymphs feed on small animals (rodents, etc.), while adult ticks bite larger animals and man. This characteristic alone is enough to account for man receiving the agent of typhus fever by way of transphasic transmission of rickettsiae by ticks, which in the larval and nymphal stages acquire rickettsiae from animal donors and transmit them to man in the sexually mature stage of their metamorphosis.

The genus *Dermacentor* also includes the tick *D. andersoni*, a typical vector of the rickettsiae of a dangerous disease of high mortality known as Rocky Mountain fever in the United States, and also occurring in natural foci. In the fauna of the U.S.S.R. *D. andersoni* ticks are absent.

Tick-bite typhus occurs in the Maritime Territory of the U.S.S.R. and is clinically almost identical with tick-borne fever of Northern Asia. The chief reservoirs and vectors of rickettsiae in nature are the ticks *D. silvarum* and *Haemaphysalis concinna*; their hosts are the Far Eastern and red-gray voles. Cases of the disease occurred in localities abounding in gently sloping hills rising to the height of 200 m above sea level and alternating with growth of Amur lime-trees, aspens, elms, and Mongolian oaks with thinned-out sections overgrown with herbage used for pasturing cattle serving as hosts for adult *Ixodes* ticks.

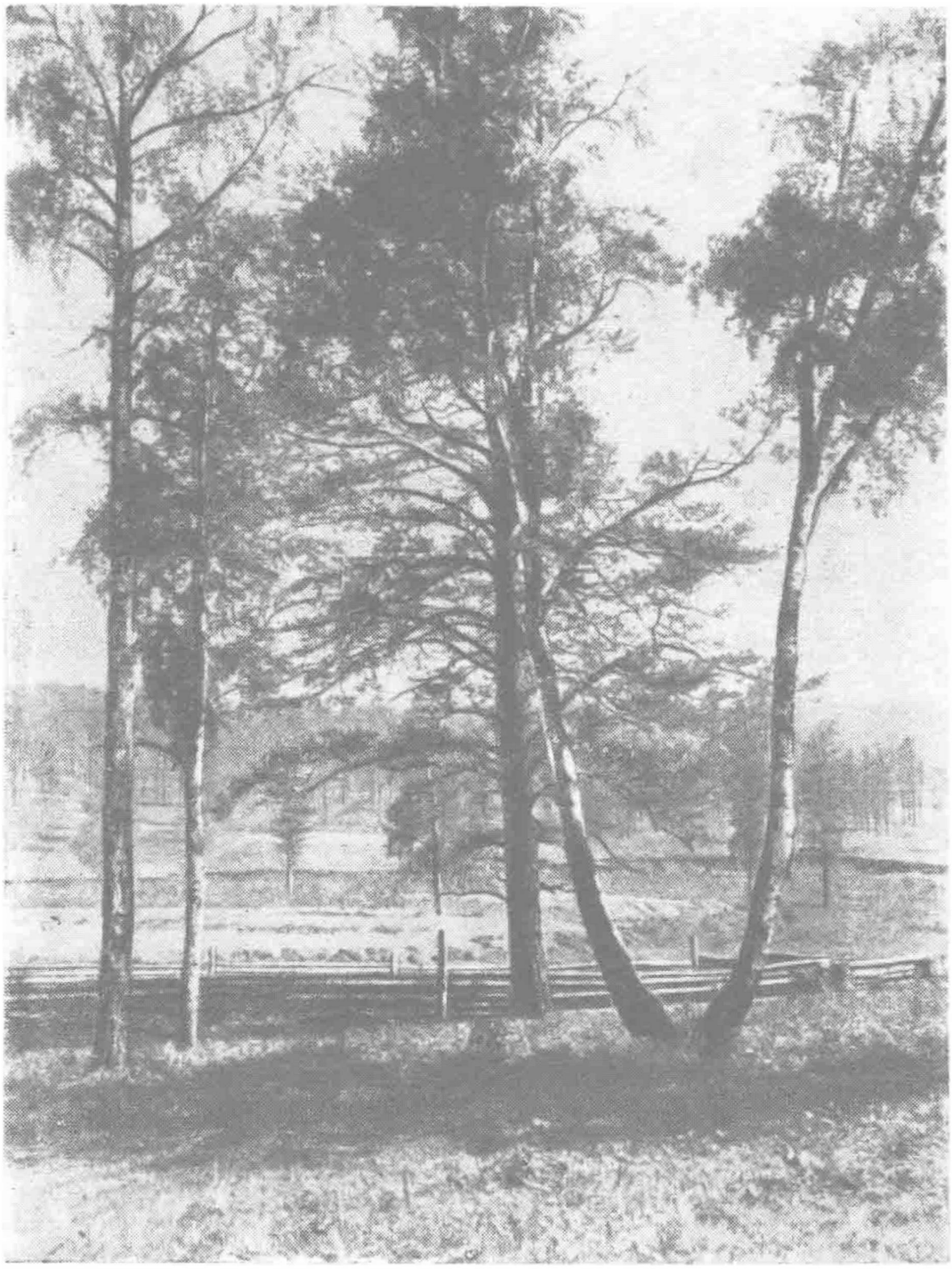
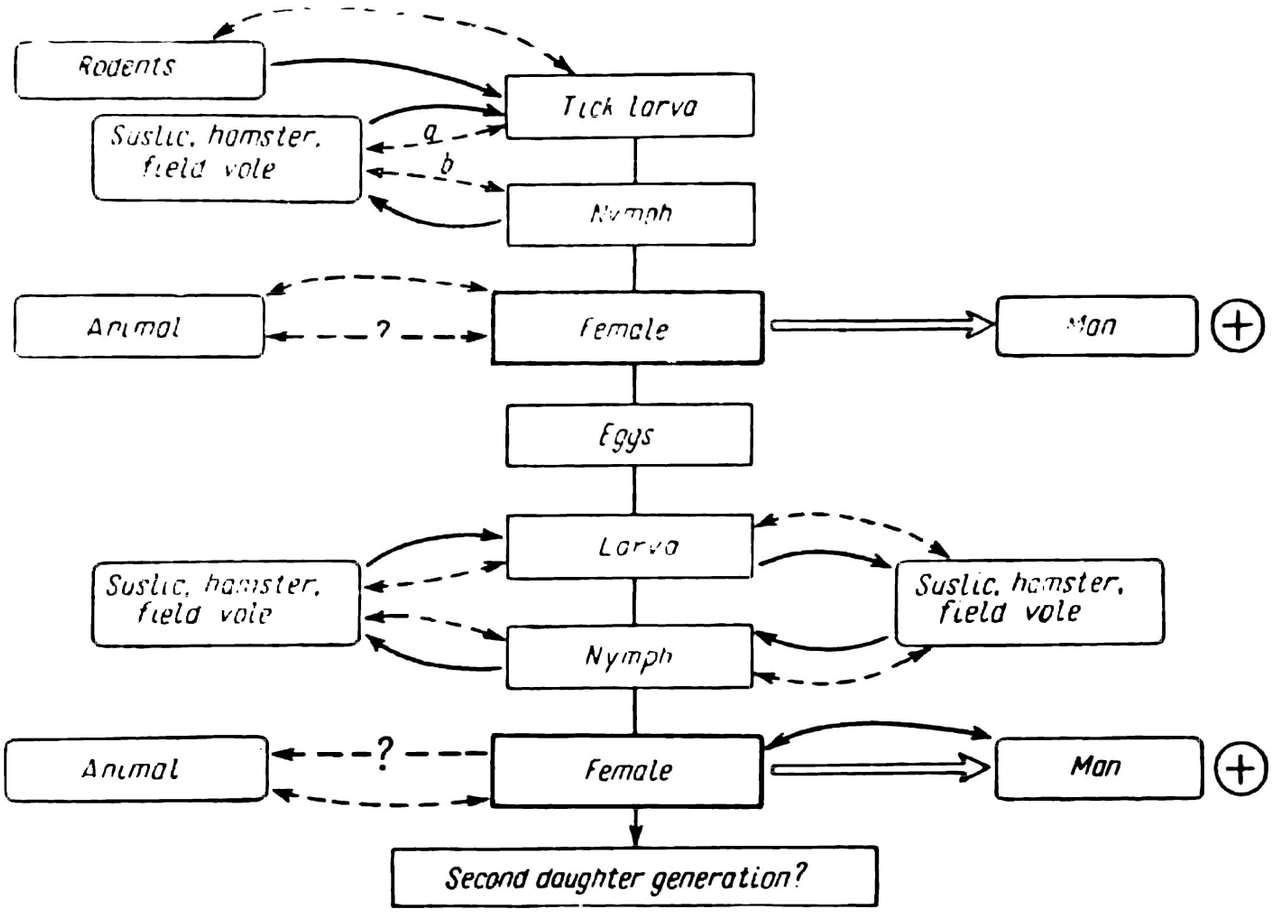


Fig. 93. A habitat of *Dermacentor nuttalli* ticks.

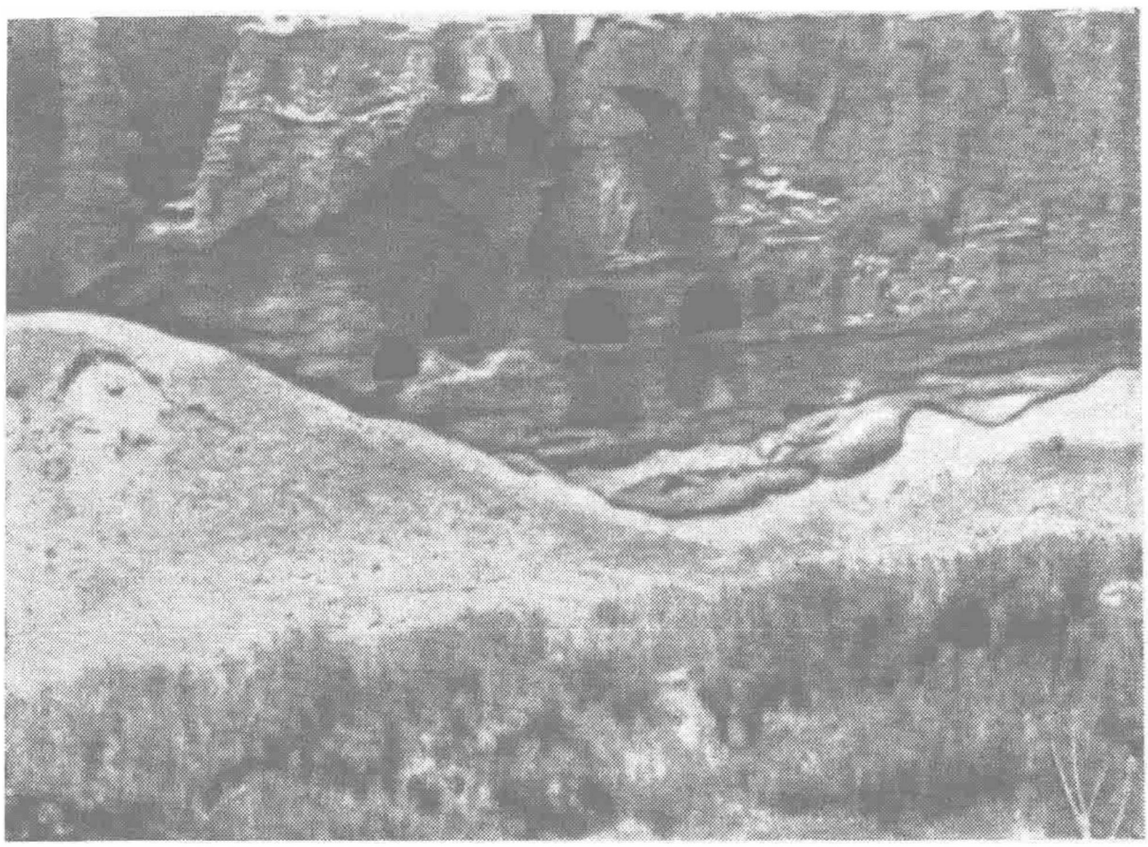
The highest morbidity rate, just as in the Krasnoyarsk region, was reported in May and June, and in the Khabarovsk Territory in June, July and August. All of the sufferers had periodically visited or permanently stayed in a locality with forests and scrub (Legkodimova and Somov, 1961).

Another rickettsiosis known as Q fever was found in Kirghizia in the above-mentioned rickettsiosis prevalence belt where *Rickettsiae burneti*, the cause of Q fever, were recovered from the placenta and milk of a cow at the time of its calving (they were absent from its blood at the time) and from a social vole (*Microtus socialis*)

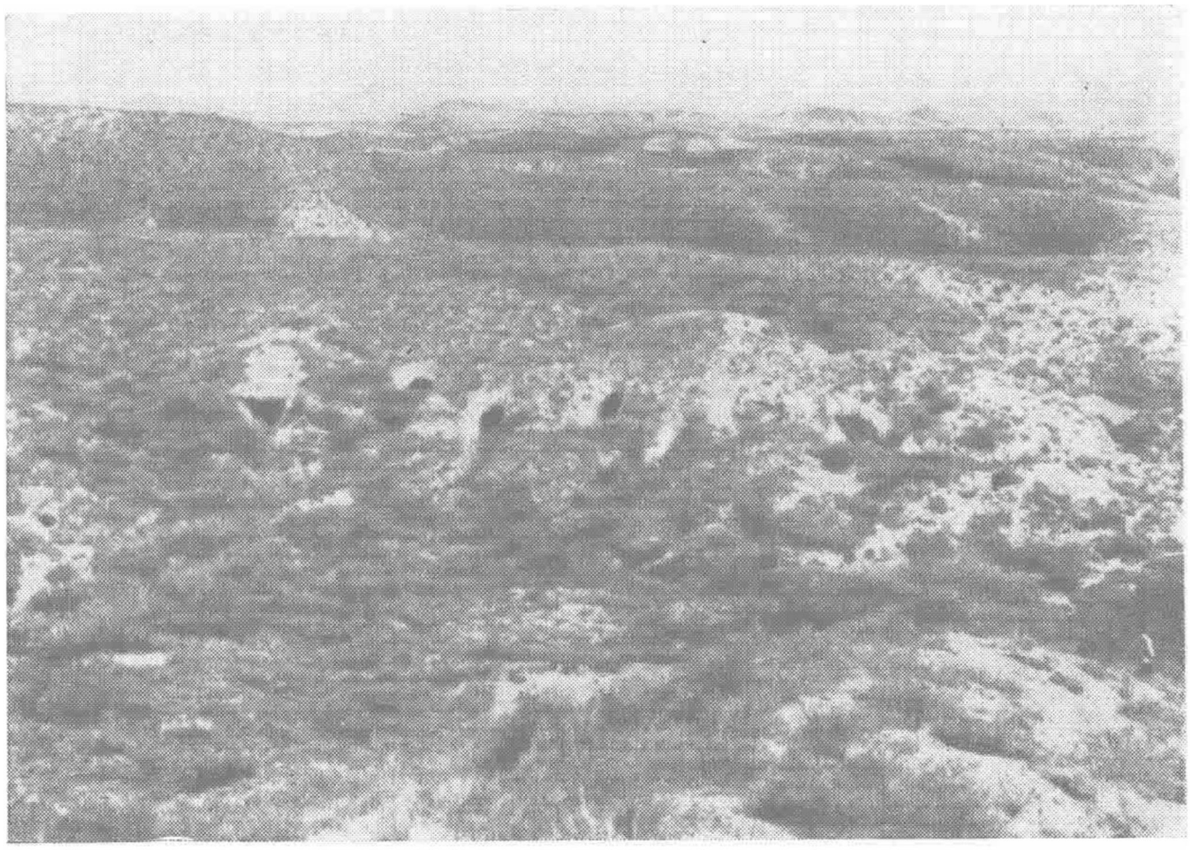



F i g. 94. Transmission of rickettsiae causing tick-borne Siberian fever by *Dermacentor nuttalli* ticks. Tick larvae and nymphs feed on rodents; female ticks bite hosts—larger mammals and man, infecting them with a pathogen acquired by larvae or nymphs from rodents and later communicated to man through female ticks by transphasic transmission. Drawing by E. N. Pavlovsky.

F i g. 95. The North-Western Kyzyl Kum desert (Karakalpakia). The landscape of a sand desert near a well in November. Photo by I. S. Soldatkin.



F i g. 96. Dug-out caves in loess precipices in the Pende Oasis of Turkmenia. Foci of *Ornithodoros* ticks—vectors of tick-borne spirochetosis.



F i g. 97. Symy (Kara-Kalinsky district of Turkmenia). Dug-out caves for agricultural needs becoming habitats of *Ornithodoros* ticks, *Phlebotomus* mosquitoes and many other insects. Photo by E. N. Pavlovsky.

F i g. 98. A burrow in a loess abode fence near Kulyab (Tadjikistan), a habitat of *Ornithodoros* ticks. Photo by E. N. Pavlovsky.

captured in an area visited by Q fever. These organisms were also recovered from *Dermacentor pavlovskyi* ticks captured in pastures at an altitude of 2,730 m above sea level, which is evidence of natural foci of this rickettsiosis existing in Kirghizia even at such a considerable height (Imanov, 1961).

*In the forest-steppe zone*, specifically in larger *clumps of woodland* (Figs. 88, 89, 90, 91) and in *forests lying near towns* relict foci of tick-borne encephalitis may be preserved here and there.

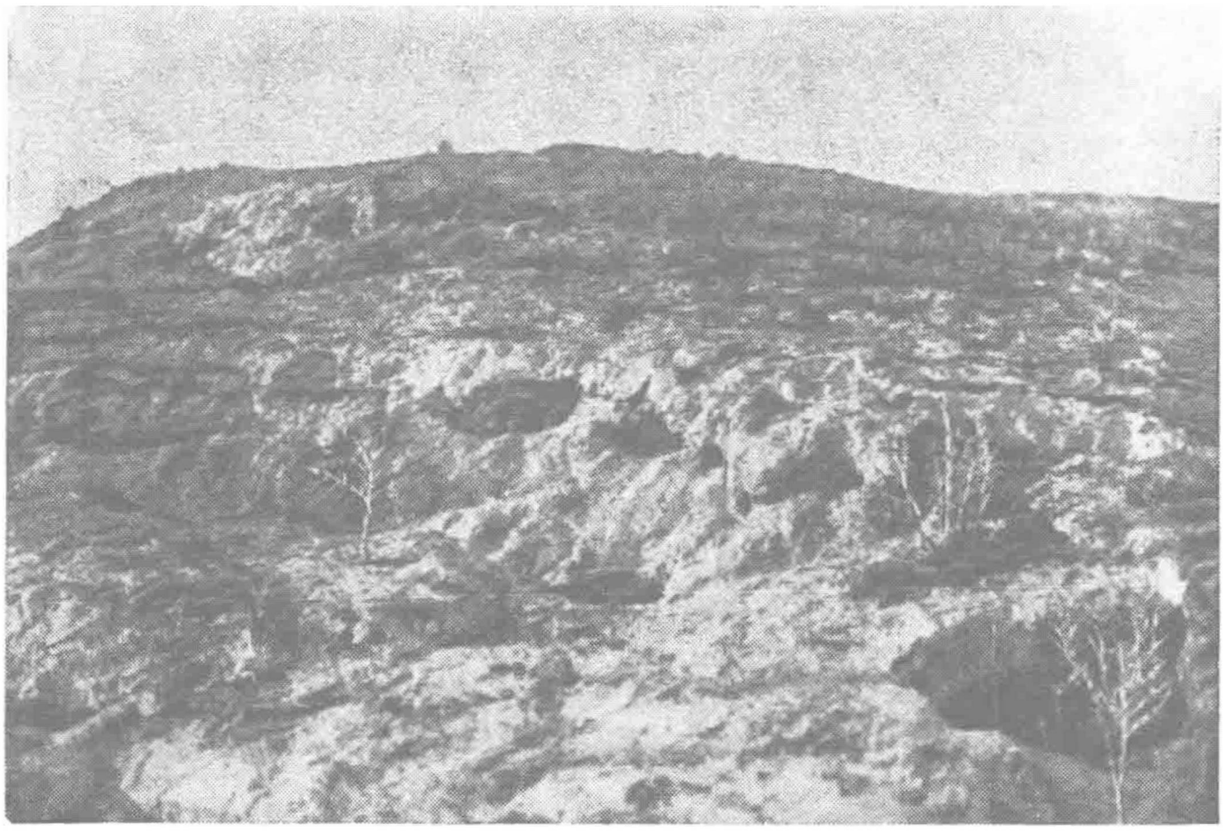


Fig. 99. Hedgehog burrows, biotopes of *Ornithodoros tartakovskyi* ticks, on the slopes of loess hills in the Kara-Kalinsky district of Turkmenia. Photo by M. V. Pospelova.

Fig. 100. The Archala valley populated by *Marmota baibacina* marmots; the site of epizootic outbreak of plague. Photo by N. G. Olsufyev.

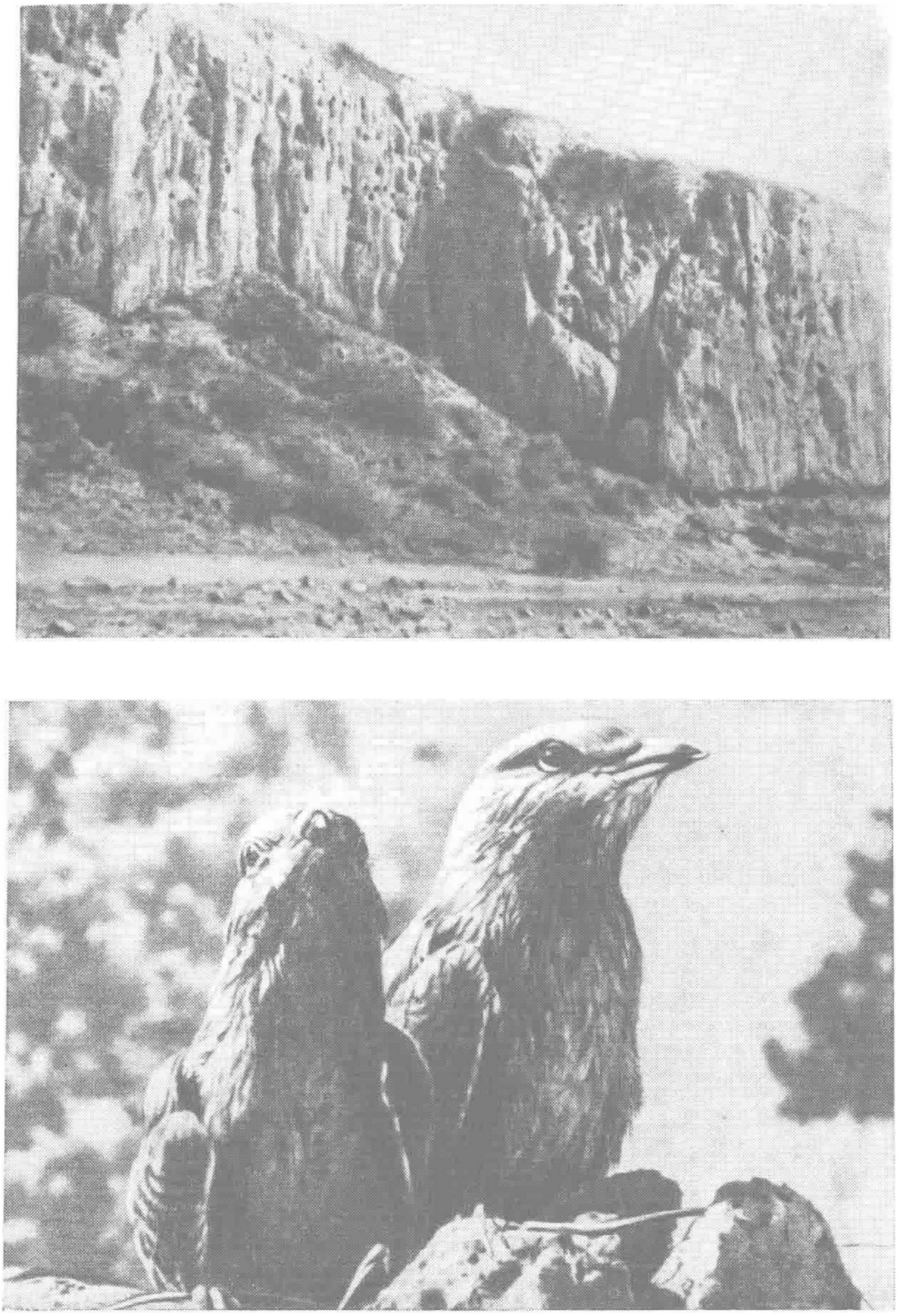
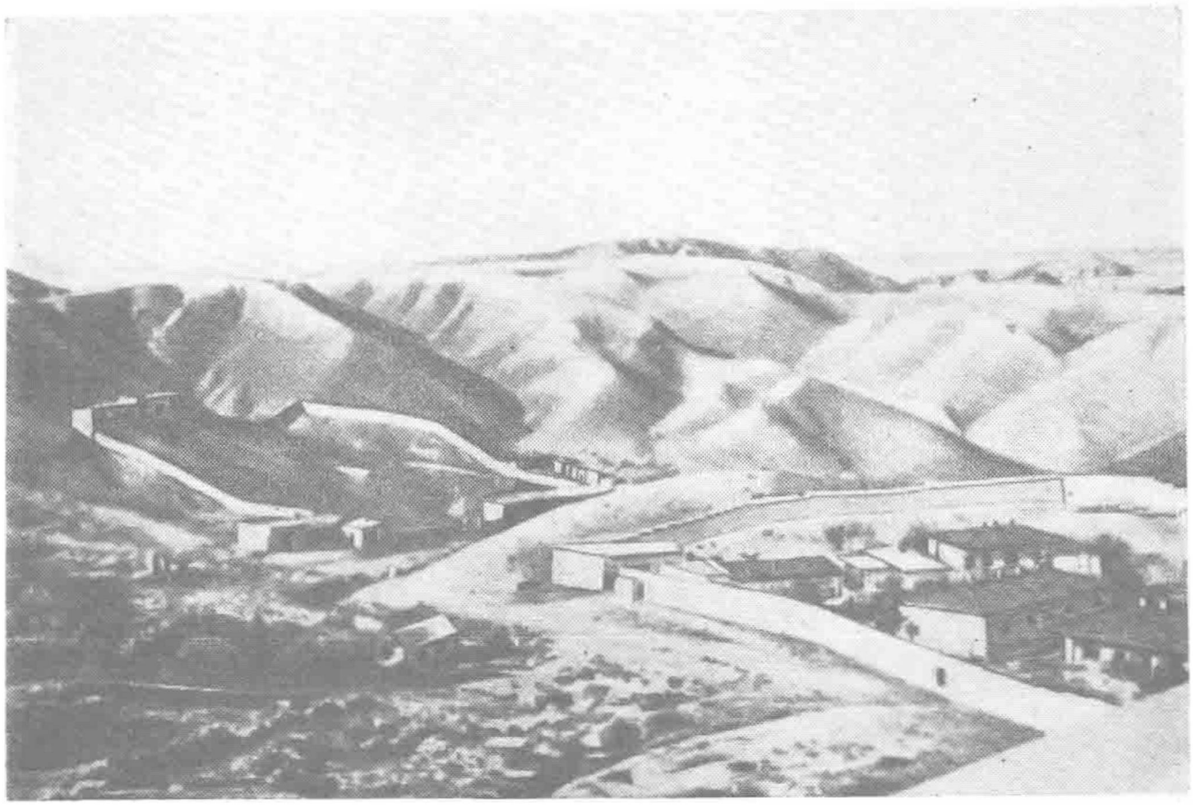


Fig. 101. The village of Tibolyai outside of Kulyab in Tadjikistan.

Above—a loess precipice with burrows of rollers and tortoise holes at the precipice base; biotopes of *Phlebotomus* sandflies and *Ornithodoros* ticks; photo by E. N. Pavlovsky; below—young rollers nesting in earth burrows in steep river banks; photo by P. A. Petrishcheva.

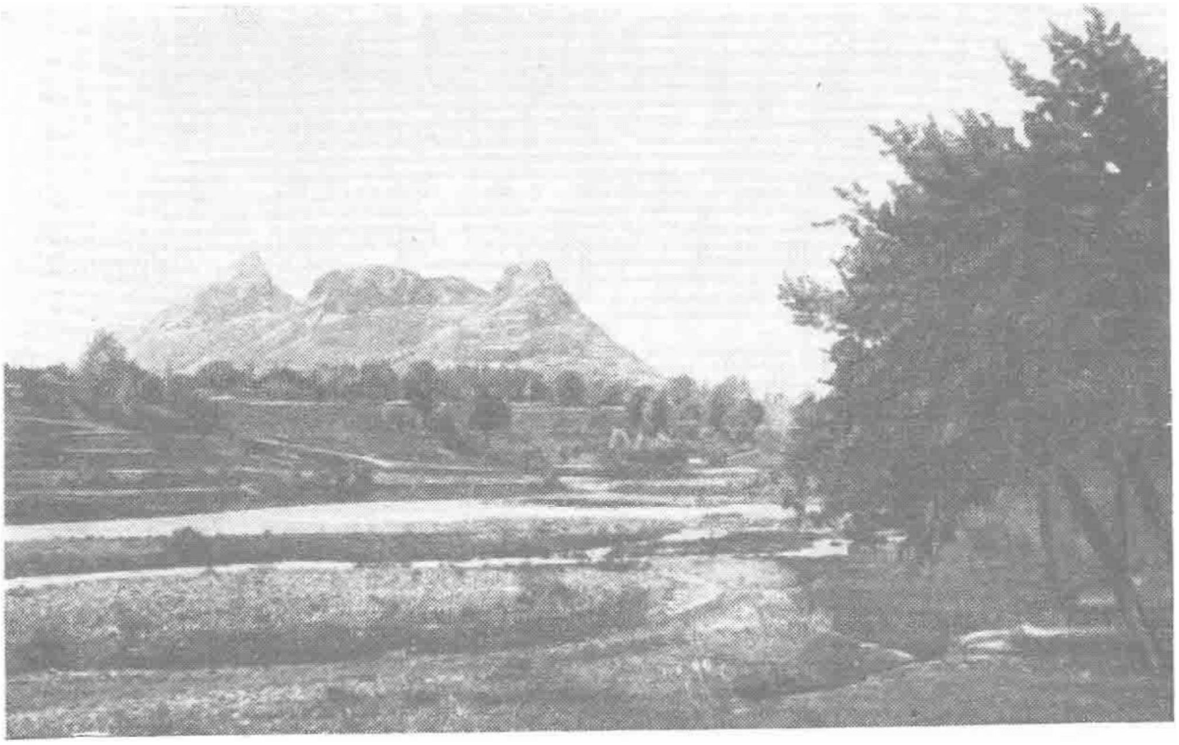


F i g. 102. Foothill semi-desert with natural foci of pappataci fever. Turkmenia. Photo by P. A. Petrishcheva.

In the forest-steppe, foci of Omsk hemorrhagic fever (OHF) may be encountered, in which a rather sharp decline may occur in the number of *Ixodes* ticks and their hosts, small rodents, owing to recurring droughts, like in the steppe zone.

In forest clumps of birch and aspen (Figs. 89, 90) harbouring forest-steppe foci of Omsk hemorrhagic fever, *Ixodes persulcatus* populations become sparse, remaining in the depth of the forest and failing to extend beyond its limits into steppe stations; *Dermacentor pictus* populations, however, assemble on the edge of forest clumps and also infest open meadows. The principal host of *Ixodes* ticks for the larvae and nymphs of both species in the period of decline is the red vole. Birch and aspen growths (Fig. 88) in the northern forest-steppe serve as stations for the survival of Omsk hemorrhagic fever virus in years when both meadow and field rodents and the dominant species of *Ixodes* ticks—*D. pictus* (Figs. 89, 90) decline in number.

It is very likely that the tick *Ixodes persulcatus* is also included, to a certain extent, into the chain of organisms through which the Omsk hemorrhagic fever virus is transmitted, i.e., is circulating in nature. The reduction of this process to a minimum restricts virus dissemination, which, in consequence of the variability of the factors of decline in relation to years, is a temporary phenomenon and may increase in scope (Alifanov, Netsky, Ravdonikas, Fyodorov, 1961).



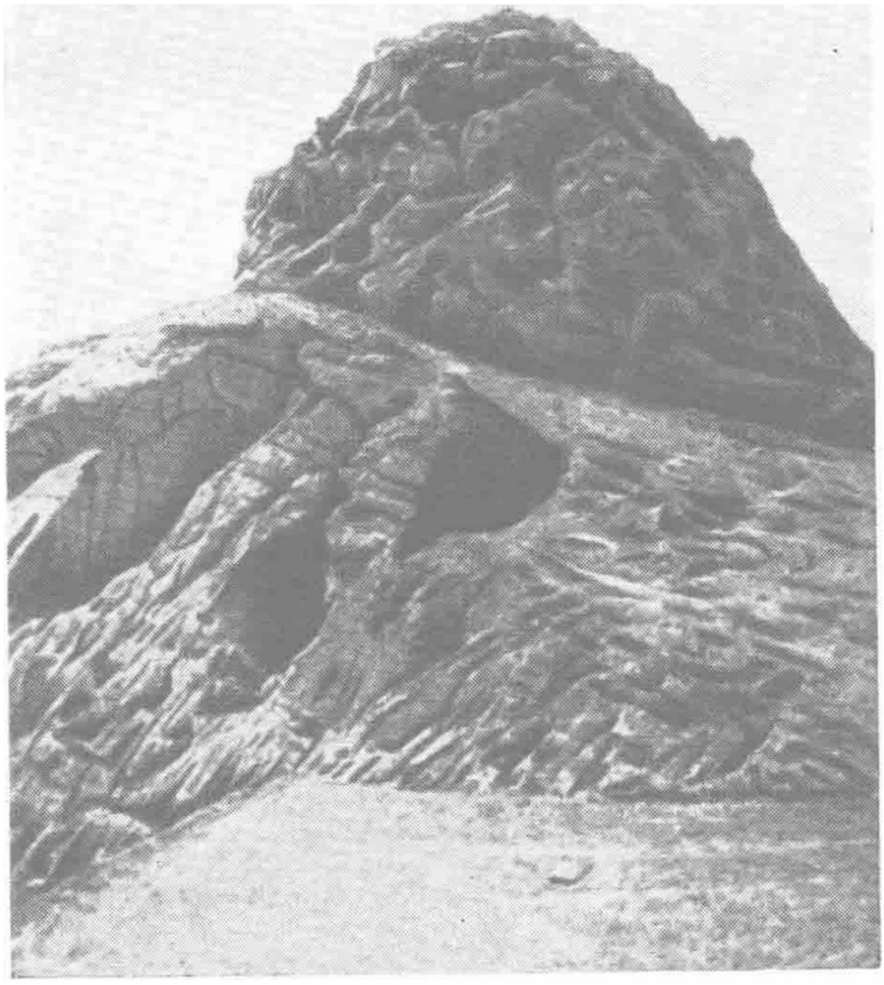


Fig. 103. Mt. Suleiman at the town of Osh in Kirghizia (above); the summit of Mt. Suleiman (below) with a cave harbouring a natural focus of tick-borne spirochetosis. Photo by E. N. Pavlovsky.

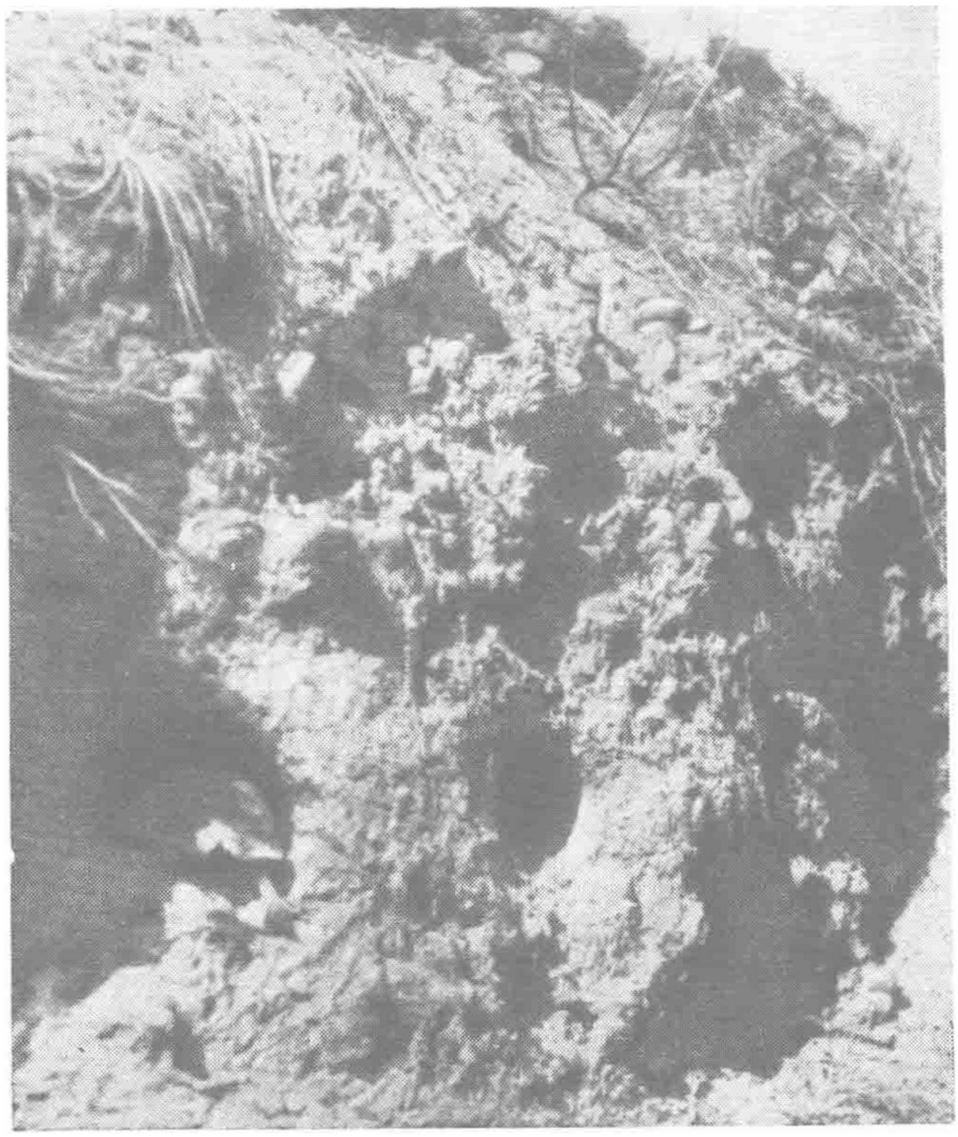


Fig. 104. A scarp near a railway track at station Seganlug outside of Tbilisi with burrows of terrestrial tortoises. A biotope of *Ornithodoros verrucosus* ticks.

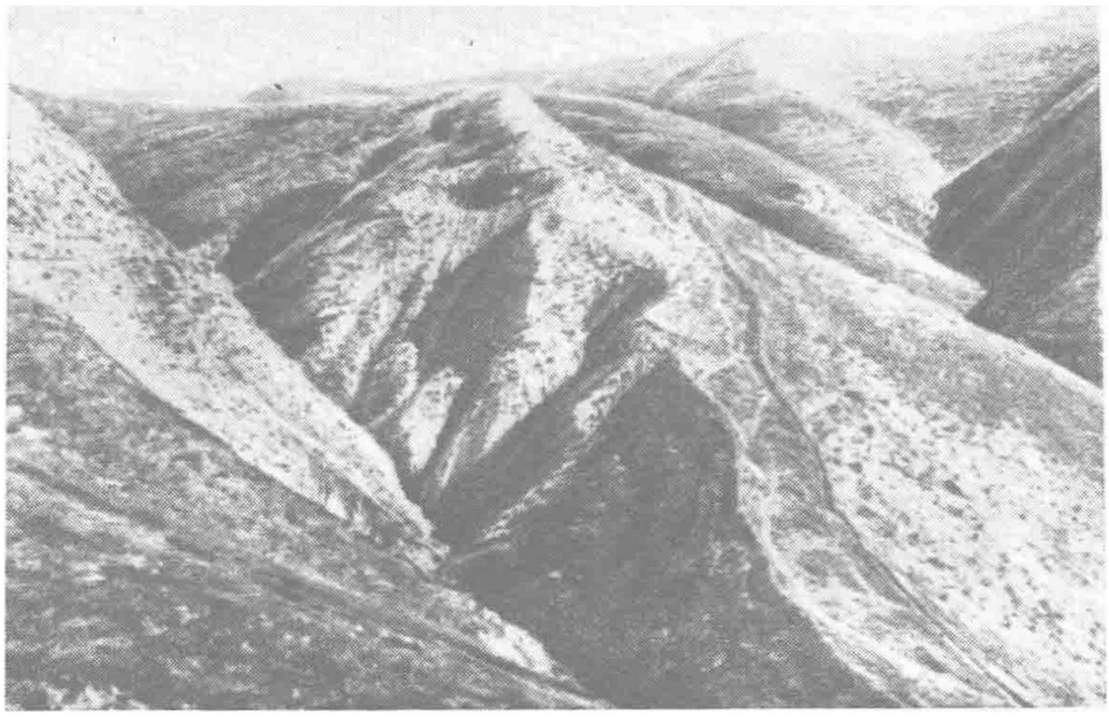


Fig. 105. The southern slopes of foothills near the Gissar state farm in Tadjikistan. A habitat of porcupine. Photo by A. I. Ivanov.

In *the steppe zone*, one finds natural foci of plague, tick-bite typhus (Figs. 92, 93, 94). Further south, in *the semi-deserts* and *hot deserts* (Fig. 95), there are natural foci of plague (Fig. 100), tick-borne spirochetosis (Figs. 96-99) and cutaneous leishmaniasis (Fig. 16). Natural foci of pappataci fever (Fig. 102) and tick-borne spirochetosis are found in *the southern mountains* (Figs. 5, 98, 101, 103-105), in the Pamirs, for example, up to the height of 2,400 m above sea level.

## MEDICAL ASPECTS OF LANDSCAPE STUDY

The study of landscapes is a part of geography, yet the definition of this branch of learning, its content and, possibly, independence are a subject of debate among geographers. The 3rd Congress of the U.S.S.R. Geographical Society held a symposium on "The General Theory and Practical Use of the Methods of Landscape Study" (Proceedings of the 3rd Congress of the U.S.S.R. Geographical Society, 1960).

The study of landscapes is of great importance for medicine in view of its specific aim, in particular, to find out the presence of natural foci of diseases in a given landscape area, characterized by its general geobotanic aspect; this is the primary aim. The second, no less important, aim is to ascertain man's influence in the present epoch or in the historical past on the primordial state of a particular landscape.

This influence brought about secondary changes which, in particular, reflected on the continuance of natural foci of diseases in nature, on the extension from them of secondary foci forming anew as a result of their transition to the immediate vicinity of man, or which led to their destruction (disintegration) and extirpation.

In the countries which have long since reclaimed their territories, like Great Britain, no landscape has remained in its primordial state. According to A. French of London University, even in Scotland's Highlands and the Wales mountains vegetation has changed considerably. The natural scenery of Great Britain has been so greatly modified by man that British geographers cannot study its modern landscape features without regard to the latest history of their formation.

Now for a few words about the situation in the Soviet Union.

In the Soviet Union one still finds virgin areas where man has never set foot and which have not been modified by human influence in any substantial degree. Such areas lie mainly in the Asiatic part of the U.S.S.R.

The landscape zones themselves are subdivided into subzones and have biotopes of diverse kind, with which the variations in the animal and vegetable kingdoms are associated.

## TYPE CLASSIFICATION OF NATURAL FOCI OF DISEASES ASSOCIATED WITH SPECIFIC GEOGRAPHICAL LANDSCAPES

For the purposes of epidemiological (and epizootiological) study it is necessary not only to find out the types of natural foci of a particular disease associated with a specific geographical landscape but also to take into account the influence produced upon it by human activity. Such type classification of natural foci of diseases may apply also to foci extending beyond the limits of one landscape zone in the latitudinal respect.

The types of foci vary with different diseases. Speaking in general, however, the following two categories of natural foci of diseases may be established.

A. *Elementary foci, which are more or less definite geomorphologically* (Figs. 4, 5, 9-11, 13-16, 92). Such a focus contains at least a minimum number of fellow members of the biocoenosis inhabiting it, which is the very fact that sustains uninterrupted circulation of the agent of a disease with natural foci, thereby ensuring the continuance of a natural focus in time. Moreover, the circulation of a disease-producing agent should be favoured by the microclimate. A classical example of an elementary focus of Penjdeh sore is an isolated rodent burrow.

It is inexpedient and erroneous to replace without good reason the term "elementary focus" by a qualitative definition (microfocus), failing to give a well-grounded motivation for this change and any qualitative, characteristic index (incidentally, a new term, mesofoci, is occasionally used in literature).

Elementary restricted foci may be isolated and complex or multiple, i.e., consisting of many connected burrows of rodents of one and the same species (for instance, gerbil colonies with a host of entrances) or also linked with much smaller burrows of rodents of another species (Figs. 16, 17).

According to the law of dialectics, quantitative changes bring about the formation of new qualities. This, however, has no impact on the very essence of a natural focus; the new quality of a complex focus proves to be a substantial physical change in the territory of a sand rat colony. The earth surface is undermined by burrows, and this change in its physical condition makes it difficult for passage: the legs of a horse sink deep in the sand, and the passage of wheeled cannons, trucks, etc., becomes impossible.

B. In contradistinction to such restricted foci there are *diffuse foci* of diseases which do not have such distinct geomorphological boundaries as has a rodent burrow or even a gerbil colony or a bird's burrow-like nest. One example of a diffuse focus is the litter of fallen leaves in broad-leaved forests, which is sometimes fairly thick (Figs. 6, 18, 19, 106). It is a perfect refuge for engorged ticks

F i g. 106. A forest in the Karelian Isthmus, with numerous *Ixodes ricinus* ticks in the litter and grass covering. Photo by N. D. Mitrofanov.

F i g. 107. The Volga delta; biotopes of water rats. Photo by N. D. Mitrofanov.

which have left their hosts. Here, ticks lay eggs from which larvae are hatched in time. The latter climb blades of grass and on occasion attach themselves to passing hosts, often small rodents which may have built their burrows within the limits of a diffuse focus of this type. In the dry litter, engorged ticks, both larvae or nymphs, spend some time getting ready for molting into the next stage of their metamorphosis: larvae into nymphs, and engorged nymphs into female or male imagoes. It is also here that molted ticks stay for some time until their chitin covers have hardened and they have become capable of attacking a new host.

Natural foci of disease also vary with the mode of infection of man. It has been pointed out above that obligate transmissible diseases can be acquired by man only where vectors of their causal agents are found. This rule applies also to the corresponding diseases with natural foci. Yet in addition to them there are infections man can acquire not only through vectors but also by many other, quite different routes. A characteristic example of such infection is tularemia. A. A. Maksimov (1960) defined the landscape type of its foci as an aggregate of infection foci homogeneous for their biocoenoses, the ways of their historical development, and modern conditions of existence, and exhibiting similar epizootiological (epizootics among animals becoming donors of infection or dying from it) and epidemiological traits.

Each type of focus has its specific structure, i.e., a combination of certain factors (Olsufyev, 1947): animal donors, recipients, infection vectors—ticks or bloodsucking insects, "abiotic environmental factors", forms of relationships between them ensuring incessant circulation of a pathogenic agent in the presence of such connections with the external environment which contribute to an indefinitely long transmission of a pathogenic agent from donor to recipient in a natural focus of disease.

N. G. Olsufyev [1959 (1960)] distinguishes the following six types of natural foci of tularemia in the U.S.S.R.: the flood- and marshland (Figs. 51, 52, 107, 108), meadow and field (Fig. 57), forest, steppe (ravine), foothill-stream (Fig. 53) and tugai (flood-land-desert in G. A. Kondrashkin's definition, 1957) foci. The names of these types do not coincide with those of landscape zones, because such foci extend to different zones. Tularemia foci are classified according to their types in account with the specific biotopes with which they are associated.

The epidemiological significance of different types of tularemia foci is not uniform as regards the mode of infection of man.

For example, the meadow and field foci give rise to agricultural outbreaks of tularemia (mowing in soggy meadows, handling stacks of hay and straw in winter—Fig. 49, their belated thrashing, as well as water-borne outbreaks in winter). The flood- and marshland foci are characterized by transmissible outbreaks (due to mosquito

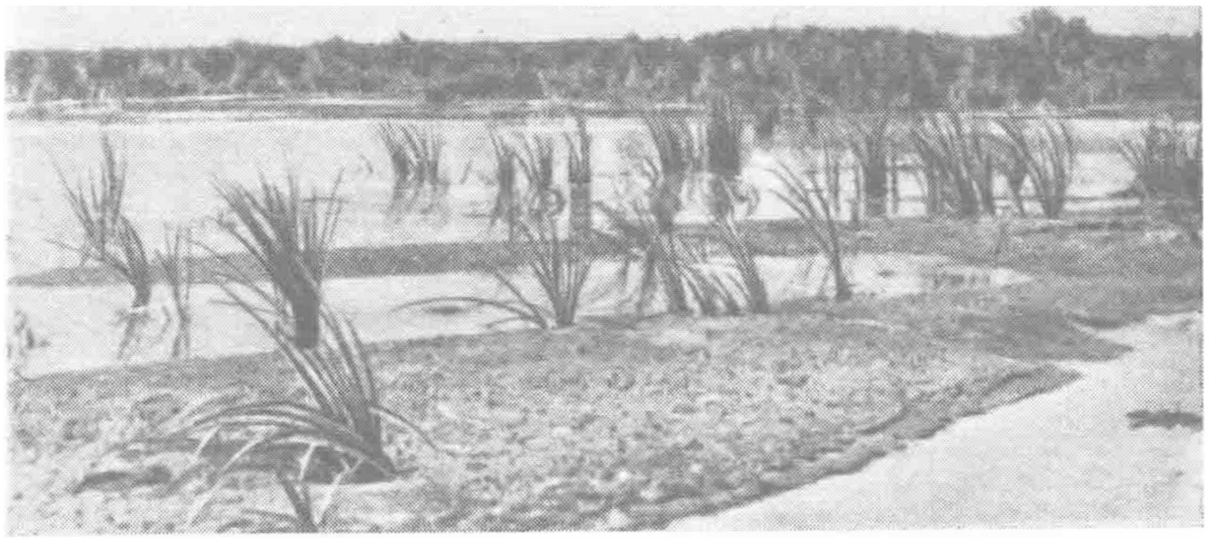
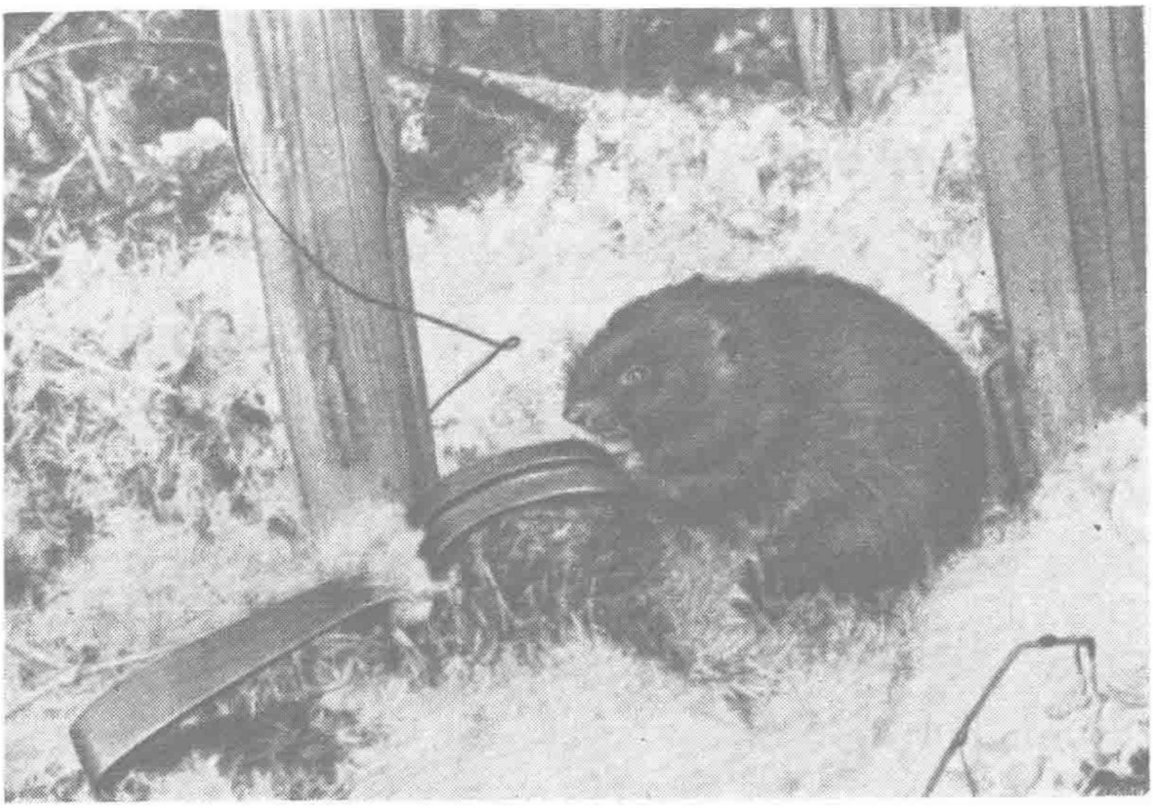
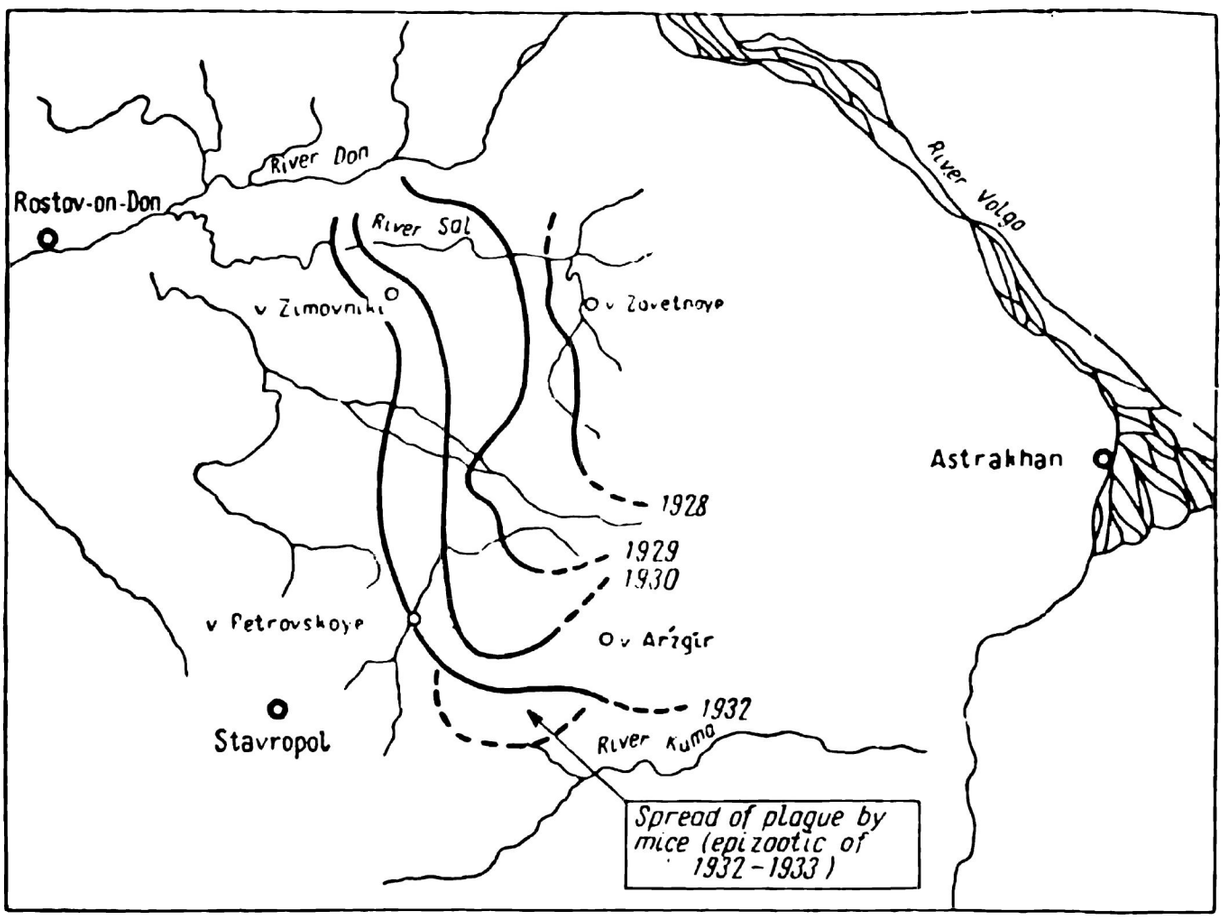


Fig. 108. The Volga delta. Water rats are met with on sandbanks. Photo by N. D. Mitrofanov.

Fig. 109. The Volga delta. A land burrow of a water rat. Photo by N. D. Mitrofanov.



F i g. 110. The Volga delta. A water rat in a trap amidst cat-tail down. Photo by N. D. Mitrofanov.




F i g. 111. Changes in the southern and western boundaries of the enzootic territory of a plague focus in the north-western Caspian region from 1928 through 1932. According to Mironov et al., 1959 (1960).

and gadfly vectors), as well as outbreaks associated with the trapping of water rats (Figs. 48, 109, 110) and muskrats; foothill-stream foci produce water-borne outbreaks in summer.

The type classification of natural foci of tularemia by various investigators is increasingly complicated by the discovery of new types and subtypes of foci. In all cases, it is necessary to specify those animal species on which a given focus depends.

In the flood- and marshland foci these are water rats and in the meadow and field foci, common voles. A number of types of tularemia foci have been studied in inadequate detail or not studied at all.

## THE CAUSES OF DECREASE IN THE TOTAL AREA OF PLAGUE FOCI

Since the 17th century the steppes in the south of the Soviet Union were increasingly influenced by a factor of steadily growing significance, namely, the colonization of the outlying districts during which parts of virgin areas were brought under the plough, settlements sprang up, roads were built, erosion came on the scene in the plains, and marmots considerably declined in number owing to their vigorous destruction. As a result of these and other processes acting in combination the formerly extensive plague prevalence area in Europe markedly narrowed. The steadily growing economic activities of man brought forth physicogeographical changes in what had formerly been the steppes, which took, from 100 to 150 years, and by the mid-19th century the leading factors sustaining the European area of plague prevalence had been completely eradicated (Mironov, 1959, p. 242).

But there may be a faster change in an area with natural foci of diseases, plague in particular. One example is the recurring changes in the boundaries of natural foci of plague in the north-western Caspian region from 1928 through 1932 (Fig. 111).

In the early 20th century, the area affected by the little marmot expanded towards west and south, which pushed back the boundaries of the plague epizootic, too.

From the total of retrospective evidence, it can be presumed that the plague prevalence area in the remote past was much larger, occupying the steppes of Southern Europe; therefore, the present area of plague prevalence in the north-western Caspian region is a relict focus, a remnant of the former huge South European steppe focus of a polyhostal type (sustained by marmots and susliks). Today, the fauna of the north-western Caspian region proper consists of 22 rodent species, but in different subzones (Ergeny, Volga basin, sand-dunes in Volga area, Ilmen delta subzone, littoral, Kumo-Manych subzone, Black Earth zone) it is subject to variation.

The most common rodent inhabitant of the majority of subzones in the north-western Caspian region is the little marmot, which is

the leading species in the epizootiological respect. At places, focal colonies are formed by social voles. The other faunal species occur in small numbers as compared to the above and are, in fact, unimportant epizootiologically.

During a long historical period, the climate in the northern hemisphere became more humid, which led to a southward displacement of landscape zones, a process which continues to this day. "At the present time, the tundra is invading the forest zone, the latter the forest-steppes, the forest-steppes the steppe zone, the steppe the semi-desert, the latter the desert" (Berg, 1947, p. 24). This takes place on a universal scale, while man's activity, which is a powerful factor influencing nature, produces sharper and more specific effects on a local scale.

The combined influence of changes in the environmental conditions and of man's activity brings about changes in the areas of prevalence of various animal species, which accounts for their different distribution today.

All this is related in effect to the geography of terrestrial animal populations. This problem and the methods of its study (biological surveys, biogeographical cartography of populations of individual species in relation to their ecology, identification of variations in prevalence area boundaries, changes in the size and density of mammalian and avian populations within the limits of their prevalence areas, quantitative zoogeographical surveys, quantitative estimation of the passage of birds through different geographical points, etc.) are discussed in the collected articles *Geography of Terrestrial Animal Populations and Methods of Its Study* (1959) edited by A. N. Formosov.

Special emphasis is laid on the present regression of the Caspian Sea and the influence of this process on the areas of prevalence of certain animals. A graphic picture of annual changes in the prevalence of the little marmot in the right-bank regions of the Volga basin was given by N. P. Mironov (1959, p. 243, Fig. 1). Also characteristic in this respect are the present boundaries of the prevalence areas of the gerbil and little marmot on the western coast of the Caspian Sea and the populations of these rodents in the Agrakhan Peninsula (Lavrovsky, 1959, Fig. 2).

These changes and their causes bring about changes also in areas having natural foci of certain infections, which are discussed in detail by N. P. Mironov (1959) describing the formation of natural foci of plague in the south-east of the Russian Federation.

Upon a retrospective analysis of a certain amount of indirect evidence, N. P. Mironov (1959, p. 241) presumed that in the Pleistocene the territory of what is now the south-eastern European part of the Russian Federation contained a polyhostal natural focus of plague of a tremendous length, which was due to the prevalence of

marmots, susliks, pikas, and other rodents in the semi-desert and desert areas of that time.

During the later gradual change of climate and in consequence of the concurrent transformation of deserts and semi-deserts into steppes the prevalence areas of many rodent species shrank, which could not but lead to the conversion of the polyhostal focus of plague into a monohostal one, in which the leading species in the epizootiological respect, i.e., the principal carrier of the plague microbe, in the Ukraine and many neighbouring regions is the marmot (*Marmota bobac* Mill.) and on the left bank of the Volga the little marmot (*Citellus pygmaeus* Pall.).

The tall-grass steppes which have replaced the deserts have proved to be a more favourable environment for marmots, and at the same time this change of landscapes has produced a decrease in the prevalence area of the little marmot. This has had a corresponding impact on the size of disease foci.

In the north-western Caspian region, the rate of epizootics depends on the time and duration of rodents' awakening from their winter dormancy. This process which occurs in spring and summer lasts some six weeks.

The migration of susliks' offspring from their maternal burrows to other burrows is responsible for the spread of an epizootic. It is at this time that susliks die by the numbers from plague, and the plague microbe can be most frequently recovered from them.

The relation between natural foci of disease and a specific landscape should be considered in change not only on the outskirts of a given landscape belt but also in its central parts, depending on the character and intensity of man's economic activity, which, having been started at a certain initial point, in the course of subsequent development, sooner or later brings about such radical changes in nature which at first glance can hardly be traced back to their initial causes.

## ELEMENTARY PLAGUE FOCI, FRACTIONAL CHARACTER OF LANDSCAPES, ALTERNATION OF SUBZONES

In the Aral Sea region, the following two types of elementary foci have been identified by N. P. Naumov and his collaborators [1959 (1960)]: (1) those found in band-shaped colonies of the large gerbil and (2) these found in their island-like or integrated colonies.

The first type is characterized by large gatherings of large gerbils at the sites of confluence of several ravines or dry valleys at the pasture borders and where valleys approach a sea. The prevalence of the large gerbil is comparatively stable, and is rapidly restored after a decline. No prolonged declines have been noted. The density of the large gerbil population in argillaceous deserts is moderate.

In these colonies there is a large variety of warm-blooded cohabitants and external parasites. Large gerbils migrate along ravines and valleys, primarily to the Aral Sea littoral. In such elementary foci the so-called bone index, i.e., the number of bones of rodents apparently killed by plague, is several times larger than in other places.

In integrated, island-like colonies, elementary foci are connected with colonies of the large gerbil in black saksaul growths in close proximity to sand or on sand dunes invading takyr soils.

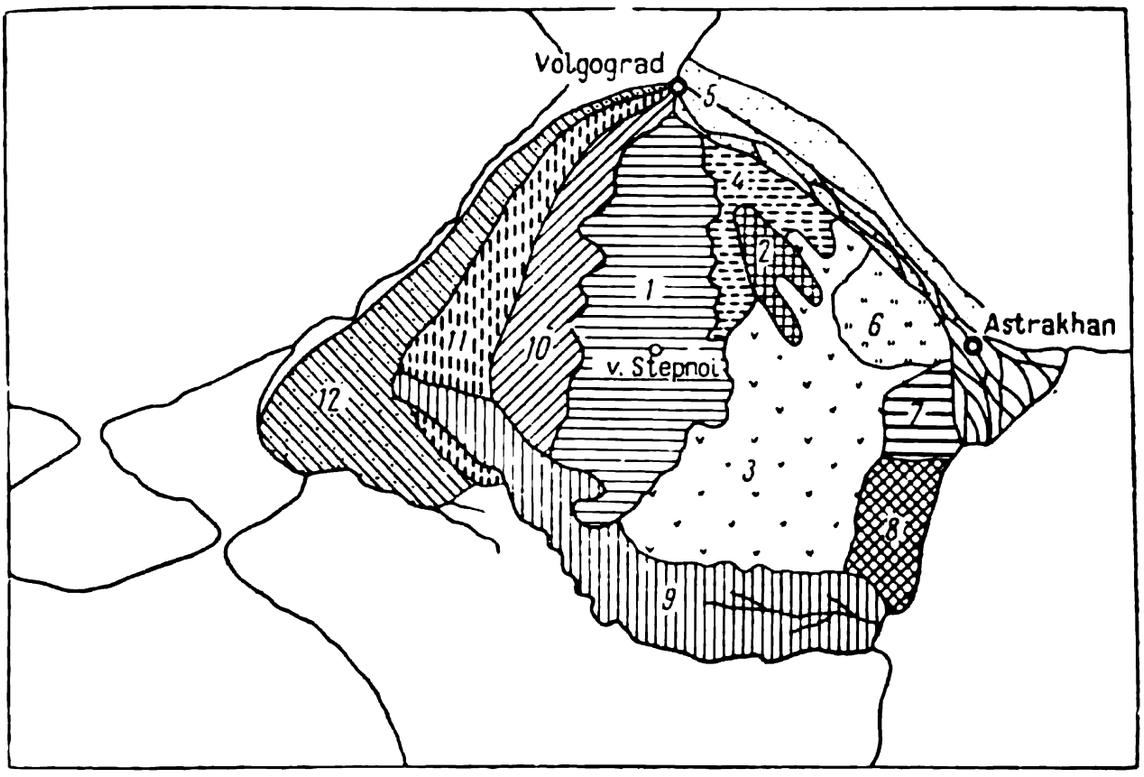
The migration of large gerbils, i.e., their repeated settlement in colonies on takyr soils is more definite and constant than on sand. The cohabitants of large gerbils' burrows are mostly red-tailed gerbils and yellow susliks; fleas are numerous here.

It is possible that elementary foci along the borders of landscapes of different types are more stable, but to verify this further studies are required. The stability of elementary foci of plague in the Aral Sea region is variable. It depends on an aggregate of causes, and is characteristic of few elementary foci. Such elementary foci of plague become the centres from which epizootics originate and spread extensively under favourable conditions.

"Extinct" elementary foci may be revived, and other foci may spring up anew where they were formerly non-existent as was the case along the Aralsk-Kazalinsk railway.

Natural foci of disease are in general peculiar to a particular geographical landscape as a whole; nevertheless, a vast territory, for example in the north-western Caspian region (Fig. 112), is mosaically subdivided into historically formed natural subzones according to the occurrence of natural foci of plague. Thus, the principal steppe landscape of the Ergeny and the Western Ergeny steppe alternates with semi-desert and "cultural", or rather anthropurgic elements: ravine beds, crop fields, plantations, melon fields, etc. Black soils are characterized by a more monotonous landscape, and susliks do not migrate as extensively there as in the Ergeny and adjacent steppes; the migration of susliks contributes to a much closer contact between animals of different species. In the sand and sandy districts of the Black Soil region susliks dig open seasonal burrows. By July and August, the burrows are, as a rule, plugged with solid lumps of earth which rules out interspecific association of susliks and substantially weakens their intraspecific contact.

In the Ilmen delta region, landscapes are so varied as to justify reference to a mosaic alternation of different landscapes. This, in turn, influences the regularity of the plague epizootic occurrence. Thus, on the Black Soils a search for plague-affected susliks and their external parasites in autumn and winter was, as a rule, futile. In the territory of the Ilmen delta region, however, rodents of almost every species are very active and constantly associate with one another; moreover, the midday and tamarisk gerbils form island-




F i g. 112. A diagram showing the division of the north-western Caspian region into landscape-ecological districts within the limits of the Volga-Don watershed and the basin between the rivers Volga and Kuma. According to Mironov et al., 1959 (1960).

The semi-desert zone: *1*—Ergeny; *2*—Deban depression; *3*—Black Soil; *4*—northern lowland steppes; *5*—Volga shore steppe; *6*—Volga sand steppe; *7*—Ilmen delta region; *8*—Primorye (littoral); *9*—Kumo-Manych district. The arid steppe zone (Western Ergeny steppe): *10*—wormwood steppe; *11*—feathergrass steppe; *12*—brown-and-black-earth steppes.

like colonies there, with which the difference in the forms of plague microbe circulation is also associated. Thus, on the Black Soils, the plague epizootic has a characteristically torpid course. The circulation of the plague microbe is retarded in consequence of failures in its intraspecific transmission by the agency of fleas passing from one animal to another within suslik populations.

The matter is quite different in the Ergeny and Western Ergeny steppes where susliks migrate vigorously, contributing to active and passive migration of their fleas. The general result is an intensive plague epizootic among susliks with an early onset of an acute infectious disease leading to agonal septicemia and death. In addition, suslik fleas are very liable to infection with *B. pestis* and readily transmit it to other animals. Therefore, the major portion of the natural focus of plague in the north-western Caspian region, including the Volga-Don watershed and the area between the Volga and the Kuma rivers, can with a great measure of accuracy be subdivided into landscape-ecological districts, a plan of which (distribution of zones, subzones and their names) is given in Fig. 112.

If the plague focus of the north-western Caspian region, delimited by the Don and the Volga rivers, can with a certain reason be subdivided into twelve subzones (Fig. 112), the Aral Sea region forming part of the natural focus of plague in the Central Asian plain incorporating the subzone of the southern steppes, semi-deserts and the northern desert with a total area of about 400,000 sq km has, just as the entire Central Asian focus, diffuse external boundaries and practically cannot be demarcated from the central and southern Kyzyl-Kum and Mangyshlak deserts [Naumov et al., 1959 (1960)]. This group of authors have subdivided this territory into 12 geographical districts, making a reservation that this subdivision is preliminary and the internal boundaries of the districts are schematic. The question is that the northern districts of the focus have been studied inadequately, and a more detailed survey of the entire focus area will undoubtedly reveal more districts subject to subdivision. The criteria by which the plague focus is subdivided into geographical districts are as follows: the floristic and faunistic distinctions, the specific composition of *B. pestis* reservoirs and vectors, and the very character of the course of an epizootic in the complex of its causative factors.

## ANTHROPURGIC CHANGES OF LANDSCAPES AND LANDSCAPE EPIDEMIOLOGY OF ZOOANTHROPONOSES

It is essential to establish the connection between natural foci of diseases and geographical landscapes modified by human activities (i.e., anthropurgic). It is natural to refer to landscape epidemiology of zooanthroponoses, i.e., diseases common to animals and man. In this connection, it is necessary to subdivide Soviet territory into definite landscape zones, i.e., to find out the presence of natural foci of disease in areas with a characteristic prevailing vegetation as well as with geomorphological distinctions. Both of these distinguishing features combined with climatic conditions determine the character of biocoenoses peculiar to a corresponding landscape. It is more precise to refer to geobiocoenoses, as is formulated by Academician V. N. Sukachev, since this term covers both the biocoenosis and its "receptacle" characterized geomorphologically (for instance, a burrow, the terrain of a hot sand desert, etc.).

It is important to determine the relationship of disease foci to natural and anthropurgic landscapes visually; the knowledge of such relationships enables the epidemiologists to undertake a provisional (preliminary) estimation of a territory in accordance with its specific landscape. This is important in the case of territories which are to be used for economic, household or some other needs when for time shortage or other reasons it is impossible to survey them for the presence of natural foci of diseases (detection of pathobiocoenoses,

animals naturally infected with certain diseases with natural foci, their relationships with the biotopes of a particular area, etc.), and it is required at the same time to give even if a conventional prognosis of the possible epidemiological hazards of such territories so as to undertake simple but effective preventive measures.

Of course, at the slightest opportunity when there is time enough and technical facilities are available, a scientific survey of the locality should be undertaken and obligatory rules for its use enforced and clearly explained to newcomers, and supervision over the established order should be instituted. The preventive measures are simple, and the basic requirement is to implement them without fail.

## LANDSCAPE, GEOBOTANICAL AND OTHER FORMS OF ZONATION OF SOVIET TERRITORY

Soviet territory is subdivided into landscape geobotanical districts mainly in the latitudinal direction; it should not be presumed that the boundaries of these districts are perfectly distinct and definitely fixed. Tracing their historical development, as has been shown above, one will realize their dynamic character, which may lead even to a complete change of landscape.

The latitudinal extension of landscape zones is at places interrupted by the floodlands of rivers flowing in the meridional direction and crossing various latitudinal landscape zones from south to north.

Different places of a landscape zone vary in details owing to the presence in some of them of mountain ranges stretching either in the meridional direction (for example, the Urals) or chiefly in the latitudinal direction (many ranges in Central Asia) as well as of large rivers and lakes.

The landscape zonation of Soviet territory does not coincide with its subdivision into constituent Soviet Republics and, inside the latter, with the administrative division (especially in the Russian Federation).

The zonation of territory is implemented for various purposes in accordance with the economic, soil, geological, agricultural and other characteristics. It should also be based on the epidemiological principle with a view to the association existing between natural foci of disease and a particular geographical landscape, which provides an outline of nosogeography, i.e., the geographical distribution of diseases with natural foci. Here emphasis should again be laid on the risk of errors likely to be made in establishing the nosogeography of certain diseases on the basis of statistics alone. The latter are concerned with a number of specific diseases subject to obligatory registration, but they are put on record only when sufferers in a given locality apply for medical aid to out- and in-patient clinics and polyclinics. This does not mean that the applicants *have contracted*

a given disease *where they are registered as cases.* Such a coincidence may take place indeed, but in case of a disease with a long incubation period (sometimes as long as one year, see pp. 156-157) an infected person may during the latent period of his disease *go far from the place where he had contracted it*, to a district where this disease is not typical at all but where it will, nevertheless, be put on record.

The presentation of such cases on a chart is misleading as regards the true geographical distribution of a given disease.

Consequently, such cases should be referred in effect to the place where the patient had actually acquired the agent of an infectious or, more commonly, an invasive disease rather than to the point where the disease gave symptoms and the case was registered upon application for medical aid. Such a registration has its own reasons and practical value, but it fails to give an authentic picture of nosogeography in individual areas and has a transitory significance.

If the presence of natural foci of diseases is attributed to definite geographical landscapes, such connection should be described in detail according to the geobotanical character of vegetation which may have certain peculiar features in different parts of a given landscape zone (vegetative facies) and various biotopes with which natural foci of diseases are associated.

# CHAPTER VIII

# PROPHYLAXIS OF DISEASES WITH NATURAL FOCI AND ERADICATION OF NATURAL FOCI OF DISEASES

## GENERAL PROPHYLACTIC MEASURES APPLIED TO MAN AND TREATMENT OF TERRITORY WITH NATURAL FOCI OF DISEASES

Prophylactic measures applied to a susceptible population residing in an area with natural foci of transmissible diseases and sterilization or eradication of these foci are important practical tasks facing the health services in utilizing the theory of natural nidality of transmissible diseases.

Within the first task the primary measure is individual and collective protection of people against aggressive vectors of the agents of transmissible diseases with natural foci. Among such measures is the use of protective nets suggested by Academician E. N. Pavlovsky (Fig. 113) to keep off winged bloodsucking dipterons (punkies) including vectors of malaria, cutaneous leishmaniasis, kala-azar, pappataci fever, tularemia, Japanese (mosquito-borne) encephalitis and lymphocytic choriomeningitis. Dimethyl phthalate should also be applied widely. It is spread on the face or hands per se or as a constituent of repellent pastes.

In the treatment of closed night lodgings and rooms portable aerosol cylinders designed by Nikolayev and Korovin are convenient for spraying tent sides with DDT, freon and pyrethrum.

To keep off non-flying vectors (ticks), persons staying in an infested area should tightly button up their clothes, tuck the shirt under the belt, tie up the cuffs, and have their trousers tucked into the high boots or tightly wrapped round them so as not to leave an opening, however small. It is helpful to wear a set recommended by Chaghin: a protective net worn round the neck like a scarf and cuffs made from similar netting and sewn to the sleeve ends.

Sometimes it is necessary to wear overalls leaving open only the face and hands. In addition, one should take off one's clothes and examine one's body twice daily so as to remove ticks, if any. One

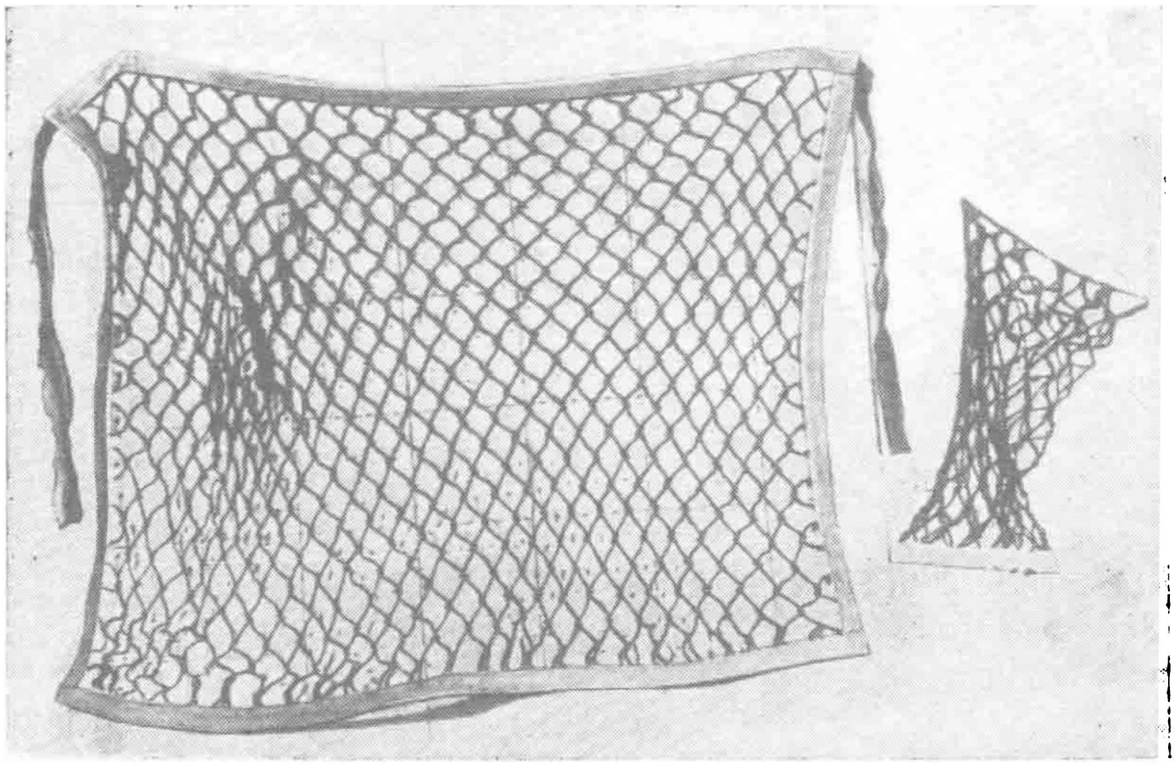


Fig. 113. E. N. Pavlovsky's protective (punkies-repelling) net. When fastened to the head covering, it leaves the face open. At right is a cuff from such net.

should constantly be on the look-out for ticks crawling onto one's clothes, so as to capture and kill them.

Medical personnel should inform the public of the need for such safeguards through the medium of health education and instructions on the application of the above-mentioned prophylactic measures.

Preliminary estimation of the epidemiological hazards of a locality is necessary for such non-specific prophylactic measures against diseases with natural foci to be taken and promoted through a serious health education work.

Protective nets designed by Academician Pavlovsky, dimethyl phthalate in sturdy vials with threaded stoppers, and freon-pyrethrum aerosol cylinders should be on sale and available to the population everywhere.

The locality should also be surveyed with respect to everyday requirements. This refers, for example, to the use of water reservoirs for drinking water supply and for bathing. If horses, pigs and other animals are kept by the side of an irrigation ditch in a small village or a field camp, they are likely to contaminate water with leptospirae eliminated with their urine, which is often the case even near the banks of large rivers. Such water is naturally unfit for drinking, washing, or bathing.

Furthermore, some outwardly attractive tracts as of forestland used for young pioneer camps, summer health centres for children which provide accommodation to a great number of inmates during

the summer season may harbour latent foci of tick-borne encephalitis. Should such a hazard be suspected a strict pastime routine should be prescribed to the camp inmates. These rules should be explained to each newly-arrived group of schoolchildren, and whenever possible the camp or sanatorium surroundings should be cleaned from scrub so as to drive rodents, the tick hosts, away from the immediate vicinity of the camp, and reduce the tick hazard, at least numerically.

Let us take a concrete example relating to a district in the Kuznetsk coal basin. This district is covered by forest-steppe and taiga forests of firs, silver firs, Siberian cedars, birch-trees, larch-trees, bird-cherry trees and snowball trees. The taiga with its berries, mushrooms and cedar cones attracts many people, especially from town, as well as anglers, who frequent the banks of a large river flowing through it, game-shooters, and holiday-makers. In addition, a growing number of health centres for children, young pioneer camps, etc., are located there.

The taiga and mixed forests harbour a number of natural foci of tick-borne encephalitis located amidst the scrub which is a favourable habitat for rodents, the hosts of the *Ixodes persulcatus* ticks, rather numerous in the wild parts of the forest where much litter and wind-fallen wood is found. Cases are on record of as many as 60 ticks captured by one hunter on his clothes during one day.

About 10,000 children were accommodated at various summer health centres here. In 1954, 30 cases of tick-borne encephalitis were registered among them in one part of the forest. All sick children had been bitten by ticks.

In a comparative study of the overall morbidity rate for 1954 and the preceding two years, it was noted that most of the cases of tick-borne encephalitis occurred in town residents. In 1954, the rate of diseases, particularly among the rural population, decreased some 66 per cent, which is accounted for by the appearance of an immune (unsusceptible) stratum among the rural population owing to their frequent professional contact with nature and prophylactic vaccination. The predominance of the disease among town residents was due to the everyday (social) factors mentioned above.

Liquidation of natural foci of transmissible diseases in a locality may be partial (but effective) or complete. The system of prophylactic measures varies with the character of natural foci of transmissible diseases.

The territory of a temporary or permanent settlement should be cleaned from grass. When digging trenches and doing other earth work rodent burrows are opened in the vertical cross-section, and the external parasites of rodents may bite the workers. It is possible that some diseases of an uncertain etiology and epidemiology

are transmitted to man exactly in such circumstances, for example, nephroso-nephritis spread by gamasid ticks.

Especially important is the liquidation of rodent burrows and destruction of their inhabitants (with chloropicrin, disulphide of carbon, aerosols) with secure closure of burrows with earth, as well as the distribution of poison baits and acaricides (Figs. 114, 115). In the Soviet Union's hot desert zone this is necessary for eradicating natural foci of the desert (rural) form of cutaneous leishmaniasis, tick-borne spirochetosis, highly virulent infections, and other diseases.

In localities covered with forests and scrub it is necessary to hew out undergrowth so as impair the environmental conditions for ticks, vectors of tick-borne encephalitis (reclamation of pastureland overgrown with scrub—Figs. 116, 117).

In a steppe zone with foci of tick-borne rickettsiosis, in an area where people work and stay temporarily or permanently dry grass should be burned down in spring, since hungry female ticks of the genus *Dermacentor* dwell in it after their hibernation. Since the autumn or summer of the previous year these ticks may have carried a load of rickettsiae acquired from steppe rodents (when their nymphs had their meal of blood), and transmit them in late spring or early summer next year to people staying in the steppe (termination of transphasic transmission).

Outside the Black Earth belt herbicides should be used to destroy scrub on pastureland.

All these and other measures require estimation of a locality with regard to the presence of vectors of transmissible diseases in different stages of their life cycle and in different biotopes; consequently, medical practitioners, epidemiologists, zoologists, parasitologists, and microbiologists should know the methods of parasitological survey of a locality so as to be capable of drafting the required prophylactic safeguards for people and eradicating natural foci of transmissible diseases in advance.

When undertaking complete destruction of animal pests in a locality by various methods applied within the framework of institutions of different ministries and used against various species of animals one should make a preliminary estimation of the drafted measures from different aspects rather than from a certain single viewpoint and carry them out simultaneously. Convincing evidence is available in favour of such organization of pest control.

The use of the long-known synthetic preparation DDT for fighting vectors and insect pests was an important achievement scored during the Second World War.

The lethal effect of DDT on mosquitoes is amazing: a brief dispersion of DDT aerosol in an experimental box containing mosquitoes is enough for all of them to have their legs fallen off and die shortly. It is also important that aerosols dispersed on a wall long retain

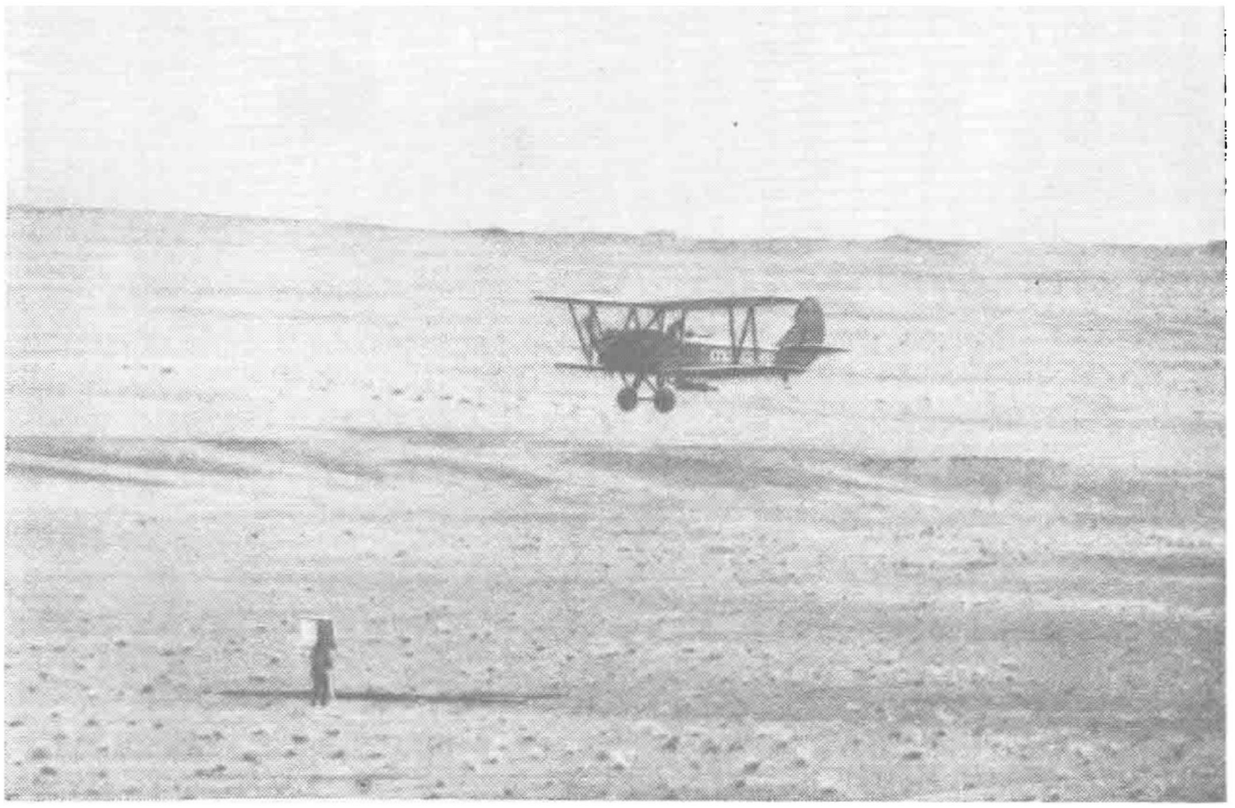


Fig. 114. Dispersion of rodent poison bait from aircraft. Karakalpakia. Photo by I. S. Soldatkin.

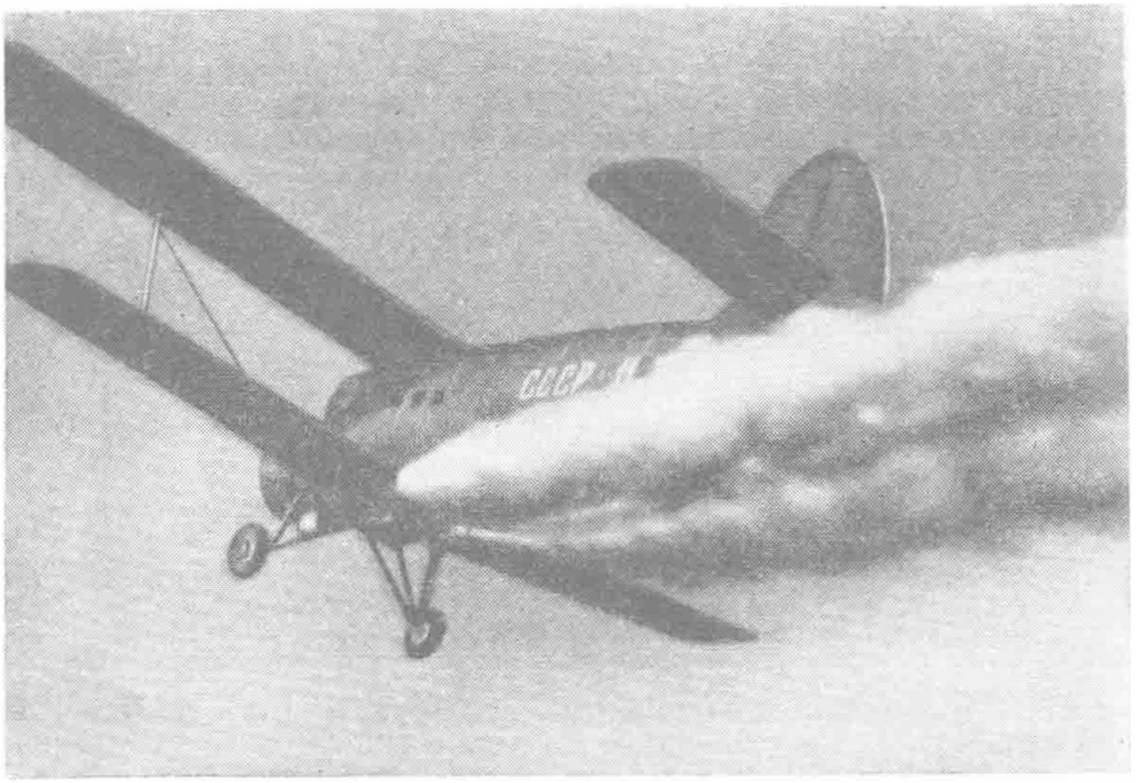


Fig. 115. Acaricide treatment of a forest from aircraft. Kemerovo region. Photo by N. N. Gorchakovskaya.

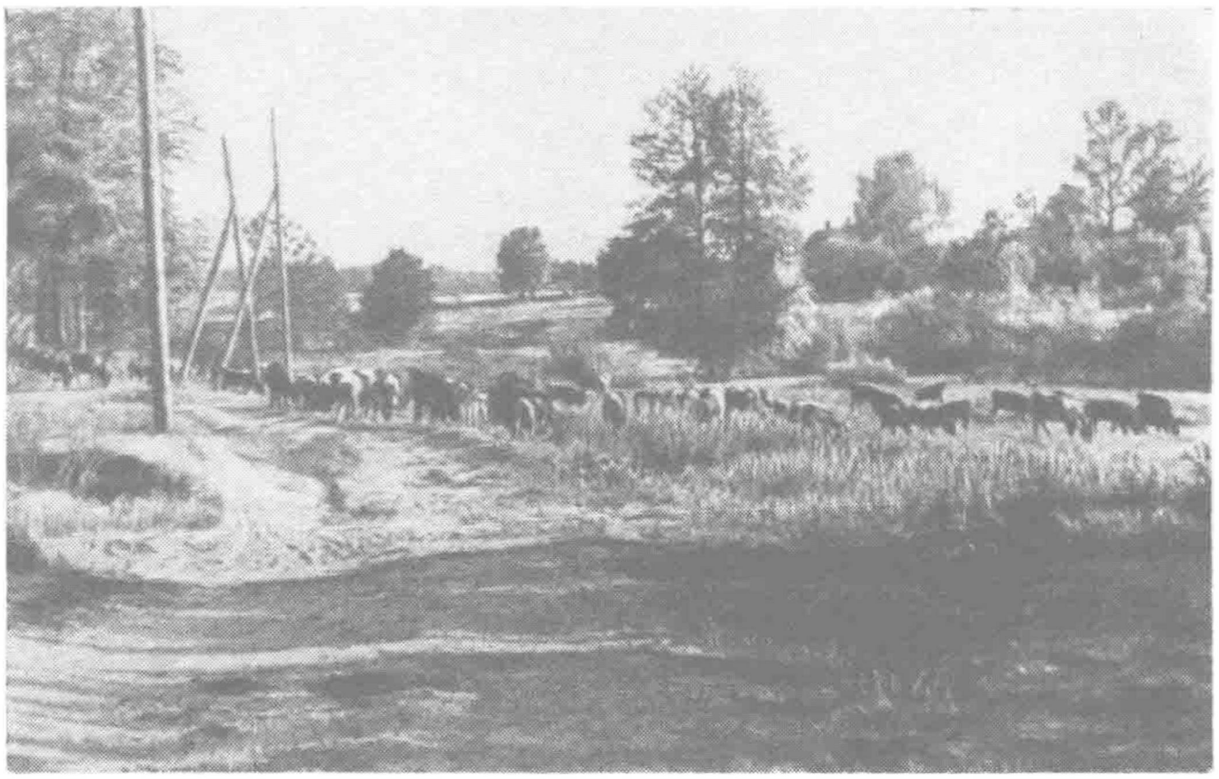


Fig. 116. Cattle on a pasture overgrown with alder, birch and osier in the Leningrad region. Photo by I. S. Avessalomov.

Fig. 117. An ameliorated hay-making and pasture area in a floodland in the Leningrad region. *Ixodes ricinus* ticks are absent. Photo by I. S. Avessalomov.

their poisonous power with regard to winged bloodsucking dipterans even after the wall has dried up.

The use of DDT for killing domestic flies finally results in the genetic evolution of generations of flies resistant to this seemingly universal insecticide. DDT is discussed in special literature.

According as the application of this preparation in various forms (spraying of powder, dispersion in aqueous solutions on walls, use of aerosols containing DDT, etc.) grew in extent, it became clear that in field conditions DDT kills not only insect pests against which it is intended but also insects harmless and even useful to man (pollinators of plants, superparasites, etc.).

Incidental destruction with DDT of some insect species harmless to human health and to the national economy may disturb the natural composition of corresponding biocoenoses, which may suffer disintegration; this destruction of the members of a biocoenosis may somewhere indirectly violate the interests of the national economy as a result of disturbance of normal biocoenotic relationships in nature.

Highly important is specific prophylaxis, which term implies massive vaccination of people intending to work or residing in localities with natural foci of diseases. This refers, in particular, to plague, tularemia, tick-borne encephalitis. Such massive vaccination of the population (with Gaisky and Elbert's live vaccine) was successfully employed against tularemia which, as has been noted above, is spread by many vectors and by various other routes.

There is also a vaccine against seasonal encephalites, and work is underway to develop new methods for its preparation. Vaccination against tick-borne encephalitis is indispensable for members of various expeditions leaving for zones with natural foci of this disease.

For a successful implementation of specific prophylactic measures among the population it is necessary to have a vaccine which would give the desired effect upon a single administration. Such a vaccine should be easily obtainable and applicable on a wide scale.

In the case of conjugate natural foci harbouring the agents of two or three diseases simultaneously it is necessary to develop a di- or polyvaccine efficacious against all of them taken together. The first attempts to produce such vaccines have already been made. There is hope that in the near future such efforts will be multiplied, but to prepare such vaccines one should know which natural foci of diseases exist in a particular locality to enable their differential application. Vaccination will also be discussed below.

## PROPHYLAXIS OF DISEASES WITH NATURAL FOCI ON THE EXAMPLE OF PLAGUE

It is known that plague epizootics were transmitted to man and the subsequent development of pestilent diseases led to epidemiological outbreaks of plague and required vigorous measures to extinguish the growing epidemic. Therefore, prevention of plague epizootics became an important link in the system of measures for plague control.

Such measures of plague control could be carried out on a great scale only by a wide network of plague control institutions (institutes, laboratories, etc.) which were set up after the October Revolution in different Soviet cities. It will be recalled that in prerevolutionary Russia there was only one antiplague laboratory at the Alexander I fort in an island lying in the Gulf of Finland not far from Kronstadt.

The chief measure within this network is the destruction of rodents and their fleas in zones with natural foci of plague. Thus, from 1954 through 1956, control operations against rodents, some of which were carriers and reservoirs of *B. pestis*, were carried out on a wide scale [Pastukhov, 1959 (1960)].

Operations of this kind have a dual significance: (1) reduction of the rodent prevalence; (2) complete eradication of natural foci of plague. Work of the first kind resulted in a radical assanation of the north-western part of the Caspian natural focus of plague. Complete eradication of the disease was attained in the Volgograd and Rostov regions and in the Stavropol territory within its 1945 borders.

The species of rodents subject to destruction vary with different foci. For example, in the southern zone of the Volga-Ural sand region and in the north-western part of the Caspian natural focus a reduction in the virulence of foci was attained through a decrease in the prevalence of sand rats despite the unsteady character of this decrease in different years. A radical assanation of the Trans-Baikal region was facilitated by reducing the marmot population. The plague control network of Siberia and the Far East is faced with the task of working out simpler and cheaper methods to keep down the prevalence of marmots in the Trans-Baikal region at a level involving no hazard of plague being spread to man as a result of adequate suppression of epizootics.

The destruction of red-tailed gerbils and their fleas with calcium and sodium cyanide mixture, mixed with hexachloran in the Azerbaidjan Republic resulted in a rather early and relatively permanent suppression of epizootics. These measures alone, however, are inadequate. Regular deratization, which has also a purely economic significance, disinfestation and disinfection of populated areas are also necessary, and subcutaneous vaccination and re-vaccination should

be applied to the entire population, which for its nearness to natural foci of disease is exposed to potential health hazards. Practical experience has proved the effectiveness of vaccination by rubbing into the skin although the intracutaneous method of vaccination, as is evidenced by experiments, gives a higher and more stable immunity. From 1954 to 1956 a total of 2,013,100 people were inoculated with live bivalent plague vaccine [Pastukhov, 1959 (1960)].

For the destruction of susliks in the vast territory of the Volga-Ural natural focus of plague aircraft were used, which sprayed grain poison baits over the infested area (Fig. 114). During this work, a group of specialists (Lisitsyn, Kucherov, Kontsov, and others, 1961) drew up standards for aircraft operations in pest control. The rates of poison bait expenditure are regulated by narrowing or widening spacings between successive plane passages. The spacings were narrowed where the suslik population was dense and vegetation was thick and abundant in the operations area. Observance of the recommended rules for aircraft operations and poison bait distribution rates made the treated area practically safe for pastured goats, sheep, horses, camels and neat cattle.

The methods of pest control in the north-western Caspian region, applied above all to the little marmot, were worked out experimentally under the direction of N. I. Kalabukhov. The most effective was the use of poison baits, i. e., oat grains coated with zinc phosphide by means of vegetable oil. After this method had proved its high efficiency it was adopted for use by the Ministry of Public Health and the Ministry of Agriculture, which were equally concerned with acquiring a reliable means of destruction of the little marmot, although for different reasons.

These methods of pest control are effective against rodent hosts of fleas, whereas the latter remain unaffected by the direct action of grain poison baits.

An important element of rodent control is *simultaneous* destruction of their ectoparasites and plague vectors—fleas hatching in rodent burrows. This was achieved by the use of asphyxiant gases (calcium and sodium cyanide mixture) and contact insecticides: hexachlorocyclohexan and DDT in powder form [Shiranovich, Shishkin, Ivanov, et al. 1959 (1960)].

Among the indirect methods of controlling susliks and other rodents of commercial value, it is important to emphasize the role of hunting.

Although the yellow suslik, the Tolai hare, the mottled polecat (*Vormela peregusna*), the wild cats—the sand-dune cat (*Felis margarita*), the steppe cat (*F. ocreata*)—and the fox are considered to be plague vectors of secondary importance, one should nevertheless bear in mind the risks of hunters and their families coming in contact with them, the more so as the domestic cat is susceptible to *B. pestis*; incidentally, until 1960 the wild cat had not been identified

as a plague carrier in Turkmenia (Fenyuk, Fyodorov and Tikhomirova, 1960).

Work carried out by a large group of specialists finally culminated in the eradication of natural plague foci in an area of millions of hectares (Shishkin, 1959). Prophylactic operations were undertaken on a mammoth scale. Small wonder, therefore, that the prominent U. S. scientist K. Meyer during his visit to Rostov-on-Don described the plague eradication campaign in the Caspian region as *operations unprecedented in mankind's history both for their scope and their effect.* The reason why they were undertaken was the discovery in the north-western Caspian region of a large number of epizootic foci, which in different years were ununiformly distributed over different regions, territories and Autonomous Republics.

The experience with rodent control in the north-western Caspian region (Lisitsyn and Yakovlev, 1961) proves that it is possible to exert an active influence on natural plague foci, reduce and suppress their infectivity for a given period.

Epizootics were driven back into the depth of the sand deserts and for six years after 1952 no plague cultures were recovered in the Volga-Ural sand region. Such a prolonged epizootiological safety had never been on record in history.

In the spring of 1959, however, plague cultures were recovered from midday gerbils, which was evidence of residual infectivity in the treated natural focus, and should be taken into account when drawing up a long-range plague control program.

There is a real possibility to accomplish the four-stage rodent control program in the Volga-Ural sand region in the near future.

In villages and localities with a dense population of rodents and their ectoparasites, it is necessary to conduct deratization and disinfestation within the framework of the general sanitation program.

## THE EFFICACY OF RODENT AND PLAGUE CONTROL IN THE EASTERN PART OF THE RUSSIAN FEDERATION

Plague control institutions carry out a massive rodent control campaign. For example, prior to 1946 there were up to 200 marmot colonies per sq km in the Trans-Baikal region, whereas later their number reduced by half and was only from 80 to 100 colonies per sq km in localities which remained untreated; where pest control measures were implemented their prevalence did not exceed 50-60 colonies and at places even less. Between 1936 and 1946, the Chita plague control station did not detect a single plague epizootic in the area of its activities. Later, in 1953 and 1954, the ecological situation in long-standing foci was less favourable for the development of epizootics, even in the presence of *B. pestis.* The reason for this was the abundance of rainfall in 1953-1954, owing to which feed

was plentiful and chances of contact between rodents searching for food became less.

L. A. Timofeyeva, I. F. Zhovty, N. V. Nekipelov, N. M. Busoyedova, V. Y. Golovacheva, I. M. Dubovik, V. I. Dubovik, R. R. Zhivolyapina, L. N. Leontyev, O. M. Petukhova, A. A. Timofeyeva, L. P. Shvedko (1957) are right in their conclusion that the absence of plague epizootics and cases of plague among humans for a number of years are evidence that the Trans-Baikal epizootic focus of plague has been considerably reduced in virulence. This, however, does not obviate the need for a thorough search for the places, forms and causes of residual retention of *B. pestis* in its natural foci, which should be carried out also in years more favourable for the appearance and development of plague epizootics owing to the existing ecological factors acting in combination.

The experience with plague control in the Trans-Baikal plague focus suggests some important conclusions. In the Trans-Baikal region outbreaks of plague had been known since 1853 (and possibly earlier). Prior to 1917, more than 25 epizootics and outbreaks of plague occurred, which took a toll of thousands of lives. In Soviet years, *human plague had been wiped out* by 1937 owing to the establishment and development of epidemiological services; in the recent past, endemic plague foci were rather frequently found in a woodless low-hill terrain covered by cereal tansy steppe plants in the central and southern parts of the Trans-Baikal region. The chief inhabitants of the steppe were tarabagans whose burrow holes were as many as 10-20 per sq hectare. As a result of pest control operations and hunting, the occurrence of tarabagans, even in heavily infested steppe areas, decreased some 90 per cent. The scope of pest control operations (from 1940 through 1956) can be sized up from the fact that they were carried out in an area of 832,000 hectares, and in heavily infested districts the number of tarabagan colonies fell as low as 0.3 and less per hectare. As a result, plague epizootics among tarabagans which had occurred in the Trans-Baikal region almost every year in the past in 1946 ceased altogether. Examination of 132,000 marmots, 39,700 Daur susliks, 191,000 other rodents and a great number of fleas and ticks from 1946 through 1960 failed to detect *B. pestis*.

For estimating the actual degree of assanation of the Trans-Baikal focus of plague, since 1956 in a steppe area of 62,000 hectares, which in the past had been the most favourable for the development of plague epizootics, the number of tarabagan colonies was allowed to increase to 1-1.5 per hectare (1960). In the same year 1960, M. F. Larionova and A. A. Savchenko (Larionova et al., 1961) recovered plague cultures from the Daur suslik and its fleas, the Daur hamster, and Brandt's vole at a distance of 800 metres from the nearest tarabagan colony although no epizootic was present there.

It is noteworthy that the animals from which *B. pestis* was recovered had exhibited no outward signs of the disease, while the recovered strains of *B. pestis*, although being capable of causing bacteremia in test animals and infecting flea vectors in their natural environment, had a decreased virulence. This fact indicated that with all indisputable achievements in the assanation of the Trans-Baikal focus of plague, the circulation of *B. pestis* continued in nature by the agency, it is believed, of such minor donors and recipients of plague, as compared to tarabagans, as pikas, gerbils and Brandt's voles. Therefore, along with the study of *B. pestis* strains with a reduced virulence and their variability it is highly important to ascertain where, or rather in which animal, *B. pestis* are preserved in their natural foci during the interval between epizootics. It becomes necessary to find reliable means of fighting rodents as minor donors and recipients of *B. pestis* during its circulation in a natural focus.

Within the framework of plague control operations carried out in the Trans-Baikal region, an important element was planned vaccination of the population, which had been started in 1940. In that year, 705 persons were vaccinated, whereas in 1960 this number grew to 21,450.

Although *B. pestis* was no longer found in rodents in the western part of the plague focus since 1946 and in its eastern part since 1951, still in the out-of-the-way districts natural foci were sustained by a sluggish circulation of *B. pestis* on a limited scale. This fact should be taken into account. Although this disease has been defeated as a human health hazard, complete eradication of its deepseated natural foci is still a problem whose solution will bring about complete assanation of a given territory from plague, which man has already learnt to keep in check.

## IMPORTATION OF PLAGUE TO SEAPORTS AND MEASURES FOR ITS CONTROL

Cases have long since been known of plague-affected rats with their fleas, mainly *Xenopsylla cheopis* and *Ceratophyllus fasciatus*, being brought on ships to southern seaports (for instance, to Batumi in 1901 and 1920). Therefore, the control of rodents and their fleas was tested and implemented as a prophylactic measure against plague. An experiment with rodent flea control was made at Batumi (Alania et al., 1959). The number of rodent fleas captured by I. I. Alania and his collaborators on living rats was three times that collected on dead rats by the prevalence index, the number of *X. cheopis* fleas being 3.3 times larger. They marked off an experimental district with an area of 35,011 sq m and with structures of all types—wooden, stone and mixed. As it had been expected, rat

holes proved to be the most numerous in wooden structures and declined in number in mixed and stone structures successively. Each hole was packed with 2-3 spoonfuls of 10 per cent DDT in powder form. Dust-bins, outhouse latrines, garrets, slits in window frames, plinths, cellar airholes, etc., were also sprayed with DDT powder. From May through December this treatment was applied three times.

The authors drew the conclusion that for plague prophylaxis in seaports and towns an all-out treatment of all structures should be undertaken rather than those infested by rodents; this largely obviates the waste of time on the preliminary identification of such structures. One of the variants of DDT powder application is the distribution of DDT-impregnated pieces of cottonwool in rat holes, cellars and woodsheds, from where rats take them into their holes. After a three-year-long total disinfestation of structures in Batumi at intervals of from 6 weeks to 2 months the prevalence of fleas—the principal plague vectors—declined at least for half-a-year.

Another, not less radical means of plague prevention in seaports is the destruction of rodents themselves and fleas parasitic on synanthropic rodents. Worthy of note in this respect are the findings for Odessa, where the environmental conditions of rodents are unusual owing to an extensive underground network of municipal facilities (catacombs, etc.), the more so as in pre-revolutionary times plague-afflicted rats were several times brought to Odessa from abroad on sea-going ships. Selected for treatment was a part of the Central city district worst infested by flea-affected rats. A. G. Azarova, N. I. Malishenko, I. S. Tinker and P. I. Shiranovich (1959) used DDT powder for apartment houses and cultural and everyday service establishments frequented by the public, and hexachlorocyclohexan powder—for underground municipal facilities, household plots, warehouses and other uninhabited structures. The selected area was subjected to an all-round treatment, irrespective of the rates of infestation by rats of individual objects (woodsheds, cellars, basements, outhouse latrines, sewer holes, dust-bins, cracks wherever they might be). Pesticides were dispersed by means of Hudson's sprayer, through a hose.

The first tour of operations was carried out in May when *Ceratophyllus fasciatus* fleas are hatched on a mass scale in Odessa. The second tour was conducted late in June and early in July. The planned third tour of all-round pest control was given up because fleas were few on newly captured rats, although this was the time when a massive emergence of *Xenopsylla cheopis* fleas had been usually observed in Odessa (September and October). Another important methodological detail should be pointed out here: the full number of fleas collected on captured living rats is usually 3-4 times larger than that found on dead trapped rats. The same result was noted by the flea prevalence index.

Examinations of fleas taken from 1,931 rats showed their infestation by fleas to decline between spring and autumn from 43.0 to 13.9 per rat, while in the experimental area this decline was even greater—80 per cent. In Odessa, the pulicidal effect of the total experimental treatment with pesticide powders was in the final analysis sufficiently high, both for the flea occurrence rates and for the flea prevalence index.

The above-mentioned authors have inferred that it is necessary to conduct disinfestation with synthetic preparations "as a primary measure applied when synanthropic rodents may be a reservoir of *B. pestis* in seaports and towns and when urgent prophylaxis or a fight against an existing epizootic among rodents is required" (Azarova et al., 1959, p. 232).

Measures against an epizootic and prophylaxis of plague in a large seaport should be carried out simultaneously within the framework of pest control operations against rats and their fleas. This is facilitated by the fact that a triple total treatment of urban structures with DDT powder along with the spraying of burrows, cracks, routes of rats' passage and other objects exerts a direct influence on rats and "ensures a sufficiently high pulicidal effect even at a later time after the appropriate operations have been carried out—in a year, a year and a half, and later" (idem, p. 237), reducing the percentage of infected rats and the general flea prevalence index for the *Xenopsylla cheopis* and *Ceratophyllus fasciatus*, which are the most susceptible to the contact action of synthetic insecticides. Speaking in general, however, the U.S.S.R. is the only country to have a wide experience in radical assanation of natural foci of plague through destruction of its carriers.

## TULAREMIA CONTROL IN THE U.S.S.R.

Major achievements have been scored in controlling another virulent disease, tularemia, which, as has been noted above, has been discovered in the U.S.S.R. at a comparatively recent time. Tularemia, as has been shown above, has a great many routes of transmission to man. Far from scattering the efforts made to cut off these routes, their variety induced the setting up of a network of tularemia control centres, like those for fighting plague, at which, just as at many other institutions of the Ministry of Public Health, vigorous steps were taken to develop a tularemia vaccine for people who, by reason of their occupation, are the most liable to contract this disease. This was how N. A. Gaisky's and B. Y. Elbert's live tularemia vaccine came into being. It is widely used in practical medicine for tularemia prevention among muskrat trappers, members of their families helping to dress pelts to be delivered to procurement

stations, workers of such stations, fishermen, and farm workers.

It should be noted that positive results of experiments on animals had to be verified on humans to make sure that the attenuated strain * of *B. tularense*, used in the manufacture of a vaccine, is harmless. The experiments made by B. Y. Elbert and N. A. Gaisky on ten volunteers proved this strain to be harmless to human health and highly immunogenic.

Some time later, N. A. Gaisky obtained, under laboratory conditions, attenuated strains of *B. tularense* having a certain residual virulence, sufficient to confer immunity.

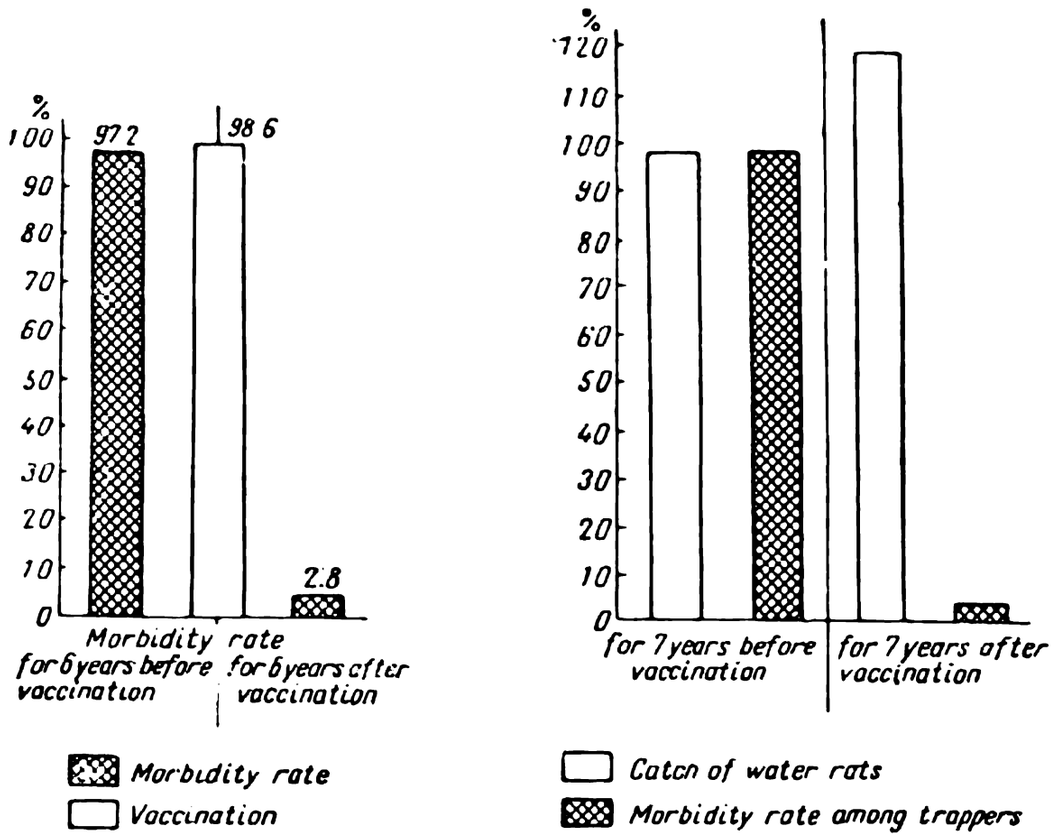
Nevertheless, the harmlessness of these strains to human health had to be verified also. This experiment was carried out at the Irkutsk Institute of Plague Control. Fifty workers of this Institute offered themselves for experimental subcutaneous vaccination. It proved harmless to human health, but further steps had to be taken to make sure of its immunogenic properties. This could be done only by an experimental infection of the vaccinated workers with a virulent *B. tularense* culture half-a-year later. These experiments demonstrated the lofty humanism of Russian medical scientists: six of those experimentally vaccinated were with their consent infected with a virulent tularemia culture. None were taken ill.

This experiment won approval for the tested vaccine, and since the end of the same year (1942) it was adopted for practical use in tularemia foci. At first, 1,300 persons were vaccinated in the Kirov region, in the next year 2,214 in the Voronezh region, and about 2,000 in Kazakhstan. Vaccinations were carried out under the personal direction of N. A. Gaisky. Subsequently, this vaccine was improved in the process of its manufacture and the vaccination procedure was made simpler. Ultimately, N. A. Gaisky, B. Y. Elbert and M. M. Faibich (cited from *Tularemia*, 1960, pp. 344-345) found an effective solution to the problem of specific prophylaxis of tularemia and developed highly efficacious live tularemia vaccines (Figs. 118, 119), the like of which are non-existent anywhere else to this day.

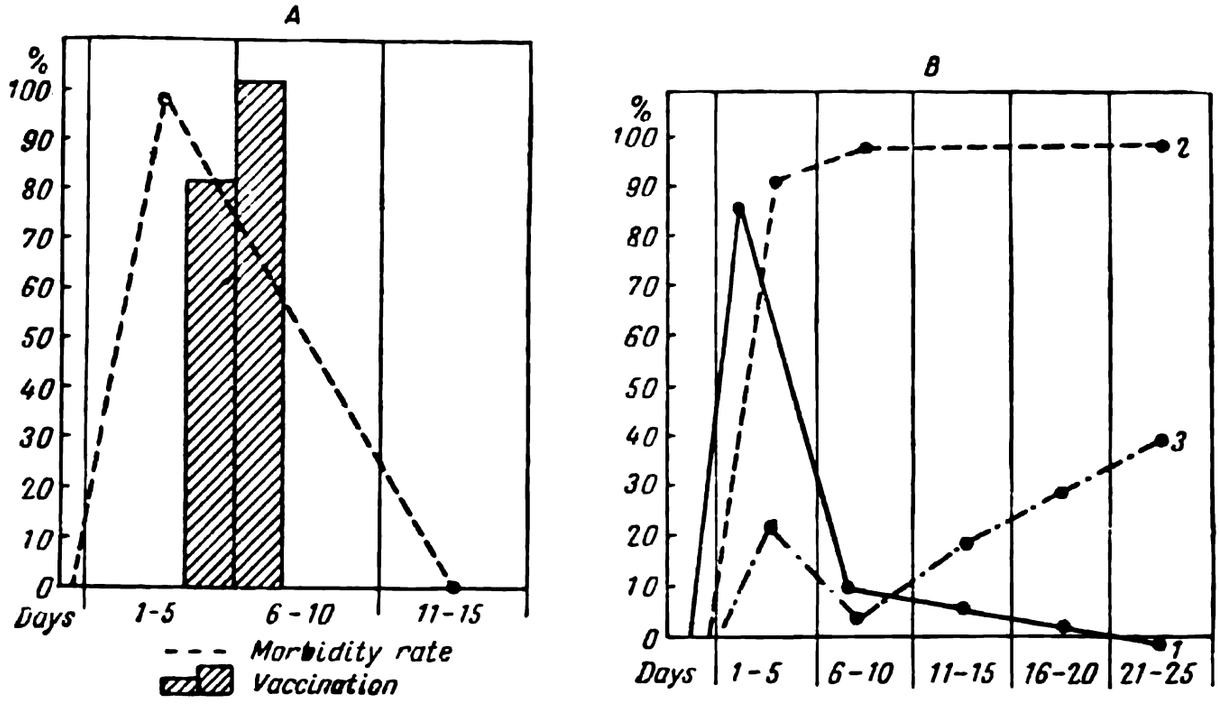
### MASSIVE VACCINATION AND ERADICATION OF TULAREMIA FOCI

From 1946 through 1958, various authors undertook vaccinations of a total of over 168,700 persons with dry tularemia vaccine dissolved in appropriate fluid [according to N. G. Olsufyev's summary data, 1959 (1960)]. Vaccinated in tularemia foci were persons who, because

* Attenuated strain is a weakened microorganism unable to cause a disease in man but capable of conferring immunity to future attacks of the disease.

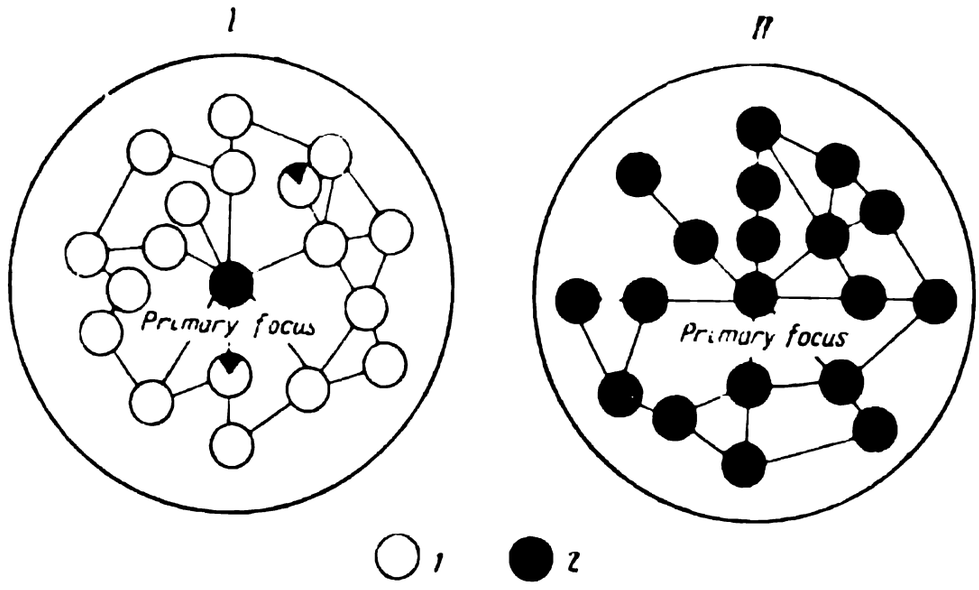



F i g. 118. Incidence of tularemia among water rat trappers before and after vaccination in Voronezh region. From monograph *Tularemia* (1960) by N. G. Olsufyev and G. P. Rudnev.




F i g. 119. Efficacy of vaccination in outbreaks of tularemia of the agricultural (thrashing) type (*A*) and the household type (*B*). From the monograph *Tularemia* (1960) by N. G. Olsufyev and G. P. Rudnev.

*1*—disease incidence during vaccination; *2*—vaccination; *3*—disease incidence in the absence of vaccination.




F i g. 120. Reduction in tularemia incidence as a result of 100 per cent vaccination.

*I*—district of 100 per cent vaccination; *II*—district where vaccination was not undertaken; *1*—points where disease was not found; *2*—points affected by tularemia. From the monograph *Tularemia* (1960) by N. G. Olsufyev and G. P. Rudnev.

of their occupation, were more frequently exposed to infection with *B. tularense*, as well as children and large populations among which tularemia outbreaks of various types (agricultural, household, hunting, etc.) occurred; vaccination of the entire population in tularemia foci was also carried out. The efficacy of vaccination is graphically illustrated in Figs. 118 and 119, showing a sharp decline of the morbidity rates; used for control were morbidity records in localities where vaccination had not been undertaken (Fig. 120). The success of vaccination is beyond doubt, and it was carried out according to plan either upon the detection of the first cases of tularemia among people or upon the discovery of a tularemia epizootic among rodents.

Vaccination has become an inalienable part of health care and tularemia control. It is recognized at present that vaccination is effective within five years of inoculation, after which period another vaccination (re-vaccination) is required.

Despite the unquestionable importance of vaccination as a preventative against tularemia in man, this measure is efficacious exclusively for man as a likely recipient of infection but fails to exert a direct influence on the very focus of tularemia in nature.

The ultimate goal is the extirpation of natural foci of tularemia, which is achieved by the use of a complex system of tularemia control measures, uniform in principle but varying in details according to the types of natural foci of this disease.

A natural focus of tularemia is sustained by a continuous circulation of *B. tularense* from animal donor to animal recipient by the agency of vectors, among which *Ixodes* ticks are veritable reservoirs of *B. tularense* in nature, as they retain tularemia microbes in their successive generations in the period between epizootics. Man, however, is a collateral reservoir into which *B. tularense* may gain entry either under *natural circumstances* (cases of transmissible tularemia), or, more often, under circumstances of *anthropurgic character*, i.e., arising from human activities (farm work, water rat and muskrat trapping, etc.).

Consequently, to extirpate a tularemia focus it is required to break every link in the chain of *B. tularense* circulation by all available means, even if indirect. This chain can be broken by various methods.

1. By control of the prevalence of animal donors of *B. tularense*. In the case of rodents, their population is reduced in density and number to a level which practically has no epizootiological importance (water rat and muskrat trapping). Direct destruction of rodents is carried out by use of poison baits, trapping ditches, physical and chemical methods. The density of the rodent population is reduced by hulling winter wheat stubbles and by other agricultural measures, such as deep autumn ploughing, mechanization and accurate harvesting, melioration of pastureland. It is important for these measures to be carried out simultaneously on vast areas and supplemented with a rational stacking of hay and straw, mowing down weeds in forest belts, at field boundaries, around villages, etc.

All this has for its aim to reduce the density and size of the rodent population and also brings down the prevalence of ticks parasitic on rodents and other animals.

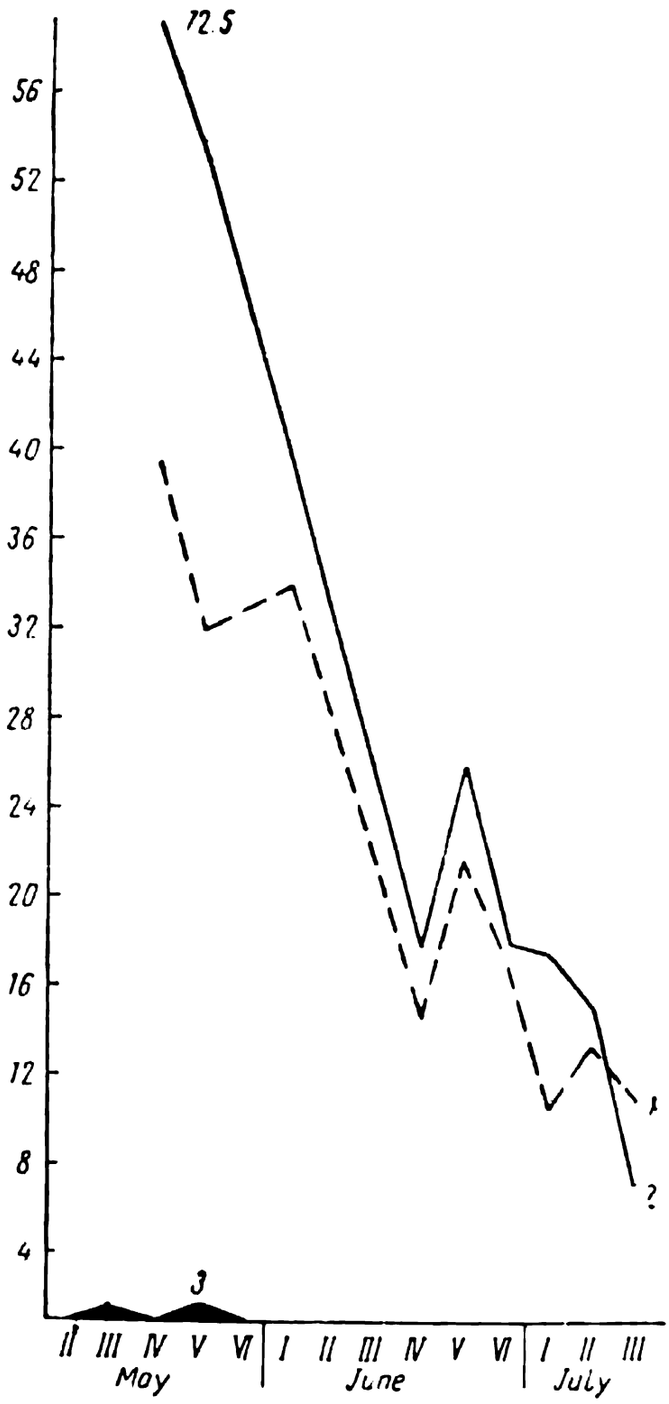
2. By control of *B. tularense* vectors themselves through destruction of *Ixodes* ticks by means of spraying vegetation with DDT and hexachloran powders or even dispersing them from aircraft.

A forest litter treated with DDT powder is lethal for all stages of *Ixodes persulcatus* metamorphosis (Fig. 121) not only in the year of treatment but also during the next four years (Gorchakovskaya et al., 1957).

3. By improving the sanitary and hygienic standards in villages.

This system of measures, however, does not obviate the need for vaccination of people.

*Ixodes* ticks are parasitic also on farm animals, with which they may be brought to villages and towns. In villages situated close to virgin or cultivated areas ticks brought by farm animals may find a suitable environment for their further metamorphosis and reproduction. Therefore, in such villages it is necessary to mow down weeds and conduct deratization. Newly-built houses and other structures (warehouses) should be made impenetrable to rodent pests, and the most important structures should be surrounded with




F i g. 121. The dynamics of the prevalence of adult ticks in 1956 in a control section and a section treated in 1955. According to Gorchakovskaya, Preobrazhenskaya and Dobrynina.

*1*—number of ticks captured per man in a control section; *2*—number of ticks collected on a flag in a control section; black (*3*) indicates the number of ticks in experimental section (all collected on flag). During the 36 hours when records were taken the following numbers of ticks were captured: in the control section—1,958 ticks (22.8 per man-hour and 31.5 per flag-hour for the season on the average); in the treated section, only 7 ticks were collected during the same time (i.e., 0 per man-hour and 0.18 per flag-hour for the season on the average).

rodent-trapping ditches. The meadows adjoining a village should be reclaimed by destruction of tussocks and useless brushwood; hay should be stacked further away from houses; the practice of using roofs of various structures for storing hay and other farm produce should be discontinued, and so forth.

Today, instructions have been drawn up for tularemia control in its foci of variable type: in localities where infection can be acquired from winged bloodsucking dipterans and ticks, where hares are hunted and used for food, where tularemia outbreaks occur as a result of hunting commercially valuable animals, where open-air water reservoirs are used in agricultural-type foci, where household outbreaks of tularemia occur in its flood- and marshland and foothill-stream foci, at farm produce-processing establishments, at abattoirs and meat-packing plants, and such specific and rarely found sites as entrenchments and trenches.

In tularemia foci, health education should be carried out among appropriate population groups. But the most important of all is the need to implement a complex of tularemia control measures, since none of them, if taken separately, can bring about the desired effect.

The massive vaccinations of the population in conjunction with other measures taken within the framework of tularemia control served to reduce the annual tularemia incidence in the U.S.S.R. from 1951 through 1959 21 times on the average as compared to the preceding period from 1945 through 1950 *.

The complexity of the tularemia control scheme and the need for supervising its realization required the setting up of a network of tularemia control centres (departments for highly virulent infections at regional, territorial and republican sanitary-epidemiological stations). Great as the progress in tularemia control may be, it is too early to rest on laurels, and further efforts are necessary on the part of these institutions so as to improve and widely apply well-grounded tularemia prevention methods with a view to assanation and extirpation of its natural foci.

## ASSOCIATED VACCINES

One may find in nature the so-called conjugate foci which simultaneously harbour agents of two or three transmissible diseases, each being sustained by the circulation of its specific microorganism among the corresponding donors and recipients. Consequently, in such polyvector foci non-immune persons may acquire two or three different diseases from different vectors. This poses the important

* At least until 1960, when the manuscript of "Tularemia", edited by N. G. Olsufyev and G. P. Rudnev (p. 345) was delivered to the printers.

practical problem of simultaneous immunization with live vaccines against two or three highly virulent diseases. It has been shown in simple form that a mixture of two vaccines—against tularemia and brucellosis—administered by rubbing into the skin or subcutaneously in experiments with guinea pigs causes the formation of antibodies and, consequently confers immunity against these diseases. The reaction of the guinea pig body to inoculation with a mixture of two vaccines is not more intensive than that exhibited by a control guinea pig immunized with one live vaccine. A mixture of two vaccines is called an associated vaccine. The mixture in question is harmless to man and immunogenic with regard to tularemia and brucellosis (Amanzhulov, 1956; Amanzhulov and Rementsova, 1958, et al.).

Further bold steps were taken by scientists. N. F. Kalacheva (1958) immunized guinea pigs with live vaccines against tularemia and plague, and N. K. Vereninova and her collaborators (1958) made successful experiments also with guinea pigs to afford them immunity against three diseases—tularemia, plague, and brucellosis.

If a live vaccine is used for such experiments, the author's theory of parasitocoenoses is applicable here. Attenuated in live vaccines, microorganisms in an associated vaccine inoculated to guinea pigs do not hinder one another but act in *combination*; an associated vaccine against tularemia and anthrax, however, inhibited the development of immunity against the latter. All such experiments are but the first steps towards the development of combined vaccines against various diseases; the combinations of vaccines may be varied and open up broad vistas in experimental research in various directions.

At the Irkutsk Institute of Plague Control, E. I. Klets, R. S. Kolesnik and G. P. Vyborov (1961) tested the stability of acquired immunity against brucellosis, tularemia, and plague by infecting guinea pigs with brucellosis a considerable period after their immunization with the above-mentioned combined vaccine.

During their pathomorphological and bacteriological studies, these authors drew the conclusion that both the associated and the pure brucellosis vaccine confer (on guinea pigs) a certain degree of resistance to brucellosis, "at least for half-a-year" and that "this resistance in animals immunized with an associated vaccine must be higher than in those immunized only with brucellosis vaccine" (p. 48). The latter indicates that the attenuated plague and tularemia microbes making up the associated vaccine contribute to the efficacy of the brucellosis vaccine. These experiments were made with dry live trivaccine and brucellosis monovaccine administered subcutaneously. E. I. Klets, R. S. Kolesnik, T. G. Skalon and E. P. Potapova (1961) raised the question of using the very same trivaccine for immunization of guinea pigs against plague by rubbing the vaccine into their skin. Such immunization with trivaccine

proved harmless, slightly reactogenic and sufficiently effective against infection of guinea pigs with a large dose of a virulent *B. pestis* strain.

At the same Institute, a research was carried out for the development of a bivalent serum against plague and anthrax. The experiments were made on a horse which was subjected to complex immunization by simultaneous administration of increasing plague and anthrax vaccine doses. The bivalent serum possessed only certain immunogenic properties exclusively with regard to anthrax. The authors of this work L. E. Khundanov, E. I. Klets, E. D. Shkurko (1961) consider that the production of a bivalent serum is inexpedient, at least when using the method of simultaneous vaccination of the horse against plague and anthrax they had applied.

It should be added that from the viewpoint of the theory of parasitocoenoses the case in question is the antagonistic, inhibiting influence of the *B. pestis* on the anthrax bacterium.

# THE INTERNATIONAL SIGNIFICANCE OF THE THEORY OF NATURAL NIDALITY OF DISEASES

In 1959, the World Health Organization (WHO) under the UNO, having its seat in Geneva, applied to the U.S.S.R. Ministry of Public Health with a request to arrange a cycle of lectures for foreign specialists on the natural nidality of diseases. The Soviet Government granted this request, and in the autumn of 1960, such lectures were delivered consecutively in Moscow at the Department for Infections with Natural Foci at the Gamaleya Institute of Epidemiology and Microbiology under the U.S.S.R. Academy of Medical Sciences, in Leningrad at the Chair of Biology and Parasitology of the Kirov Academy of Military Medicine, at the Institute of Zoology under the U.S.S.R. Academy of Sciences, and, finally, in Tbilisi, Georgia, where excursions to the hinterland were undertaken for a study of its natural conditions resembling those in the subtropics. These courses were attended by specialists from Japan, Indonesia, India, Pakistan, Afghanistan, Israel, the U.A.R., Spain, Algeria, Yugoslavia, Bulgaria, Czechoslovakia, and Poland. At first, the WHO was represented by Prof. Svetanovic of Yugoslavia, who upon his departure was succeeded by Prof. Wolf of the Netherlands. Among the lecturers were Prof. Rosický of Czechoslovakia, Prof. Wolf and Prof. Audy of the U.S.A. The audience highly appreciated the lectures, while their sponsors and lecturers were gratified to see that the interest in their subject grew on a world-wide scale.

In 1962, the WHO requested that these lectures be repeated for another group of specialists from different countries. This request was also granted, and similar courses were arranged in Leningrad and Moscow with subsequent excursions to Georgia. The composition of the audience at the 1962 courses was even more varied, and included specialists from the U.A.R., Iran, Pakistan, India, Ceylon, Burma, Ghana, Nigeria, Japan, Brazil, Venezuela, Cuba, the U.S.A., Czechoslovakia, Greece, Turkey and the Mongolian People's Republic.

In 1963, a symposium on diseases with natural foci was also held in Leningrad in accordance with a joint decision of the Minis-

ters of Health of the socialist countries who had met in conference in the G.D.R. sector of Berlin.

The symposium was attended by representatives of Czechoslovakia, the G.D.R., Hungary, Poland, Bulgaria, Yugoslavia; the U.S.S.R. was represented by a large number of participants. The major task of the symposium was to hear and discuss reports on the current status of the practice of the theory of natural nidality of diseases in individual countries, in certain parts thereof, and on the prospects for its development where appropriate research is still inadequate. An agreement was reached on the need to draw up a uniform terminology.

An exhibition of books in Russian and other languages was held simultaneously on subjects devoted wholly or in part to individual diseases with natural foci or groups thereof, which graphically illustrated the rapid increase in the amount of scientific literature and practical manuals in this field. According to preliminary estimates, the number of such books is already in excess of 2,500.

It is particularly important that growing importance is attached to departments of infections with natural foci (Gamaleya Institute of Epidemiology and Microbiology in Moscow, and other institutes concerned with epidemiology, microbiology and hygiene), while the Omsk Institute of Epidemiology, Microbiology and Hygiene has been reorganized into the Institute of Diseases with Natural Foci (for which a new building is being built) with a branch in the town of Tyumen. Research into diseases with natural foci is also carried out at other institutions in accordance with their respective programs.

Ready to render all possible assistance where surveys for natural foci of diseases are still far from being completed, we are aware of the prime importance of the most detailed study in this respect both of the uninhabited areas of our boundless country and the virgin land development areas, as well as regions where minerals are extracted, territories adjoining construction projects, and long cultivated areas where dormant but still virulent natural foci of diseases may be encountered.

There is indisputable evidence that the influence of the theory of natural nidality of diseases is growing and extending to new fields. Indeed, it is believed that its fundamentals can be applied to incommunicable diseases; there is good reason to suspect the existence of natural foci of diseases of freshwater fishes. The fundamentals of this theory (according to B. V. Dobrovolsky's report) are quite applicable to insects also, in particular to forest and agricultural plant pests. Thus, the importance of this theory grows to the degree of a general biological law governing the existence of the organic and even inorganic world (tracer elements of soil and diseases of neat cattle and man).

A definite, more or less extensive geographical distribution is characteristic of various venomous animals, beasts of prey, destructive pests (termites, nesokias, destructive to irrigation systems; granary, warehouse and household pests, etc.).

A general idea can be gained of the destructive forces of the organic world, which cause harm to human health, animal husbandry, plants, technical structures, houses, and physical resources of animal and vegetable origin.

Analogous concepts are applicable also to the inorganic world. They have to be spoken of in a general way so far. Indeed, what else if not diseases with natural foci are Kaschin-Beck-Urov's disease in the Trans-Baikal region, human endemic goiter, acobaltosis of neat cattle and other diseases caused by insufficiency of certain tracer elements in the soil. The tracer elements have their own geographical distribution, which is not continuous but is to a certain extent mosaical, or island-like, so this disease can be acquired only by those living in an area where one tracer element or another is deficient in the soil. This deficiency is reflected biochemically on plants, and by the agency of vegetable food used by man and farm animals this deficiency, like in a chain reaction, ultimately affects the health of the human population of a particular locality or farm animals pastured there. Vigorous research into soil tracer elements is underway in the Latvian S.S.R., and this example should be followed in other parts of the Soviet Union.

# CONCLUSION

For an effective control of diseases with natural foci it is necessary above all *to determine the structure of these foci*, even if modified by man. A natural focus of disease exists as long as its *causal agent continues in circulation*, yet such foci may spring up anew in formerly unafflicted areas as a result of human activities of various kinds (for example, the importation of cattle including individuals harbouring the agent of a disease unknown in a given locality) or arising from certain natural causes (importation of pathogenic microorganisms, as by migrating or nomadic birds), or from other circumstances.

In all cases, the fundamental cause to which the existence of a focus is due is *either the continuity of the already existing circulation of a pathogenic agent or the origination of this process where it was formerly non-existent* but where the ecologo-faunistic situation is favourable for its appearance and subsequent growth.

Consequently, measures for the sterilization and subsequent extirpation of a natural focus of disease amount in their theoretical implications to *breaking up the continuity of circulation of a pathogenic agent by any means likely to affect any of its stages.*

In view of the complexity of the process of pathogenic agent circulation, one has, in the final analysis, to develop *a system of such measures* as would naturally vary with the character of a particular disease with natural foci especially in conjugate foci of two or three diseases.

The system of such measures is schematically composed as follows:

I. Of measures bringing about (a) a reduction in the population of animals—actual and potential donors of a pathogenic agent to a level that is practically of no epizootiological importance, or (b) complete destruction of such animals in a given locality of variable size. In addition to direct measures against animal donors,

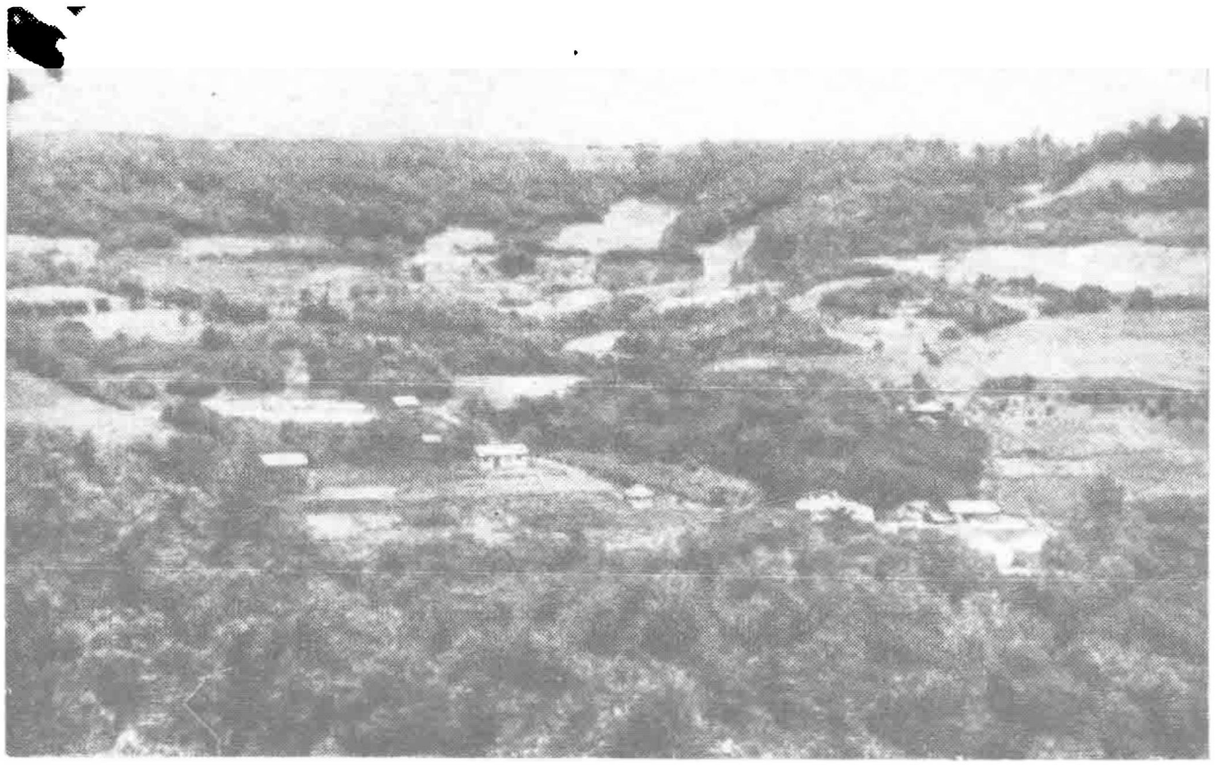
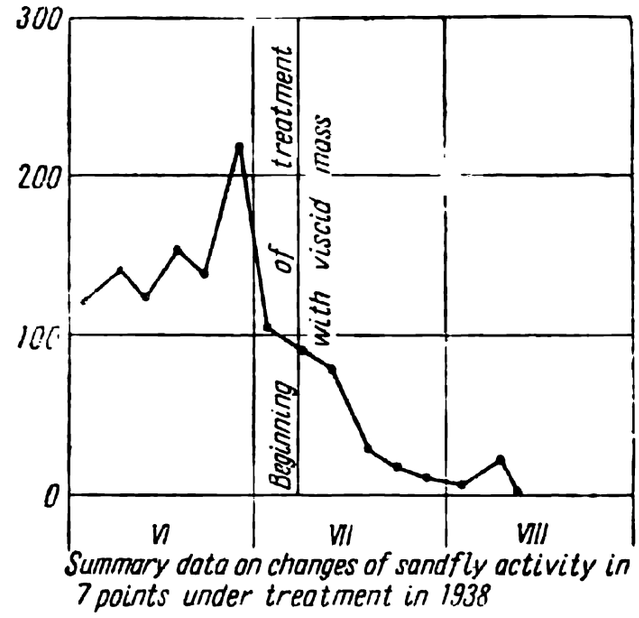


Fig. 122. Reclaimed taiga. A general view of the Mountainous Taiga Station of the U.S.S.R Academy of Sciences. No cases of tick-borne encephalitis occur in its territory. Photo taken in 1939.

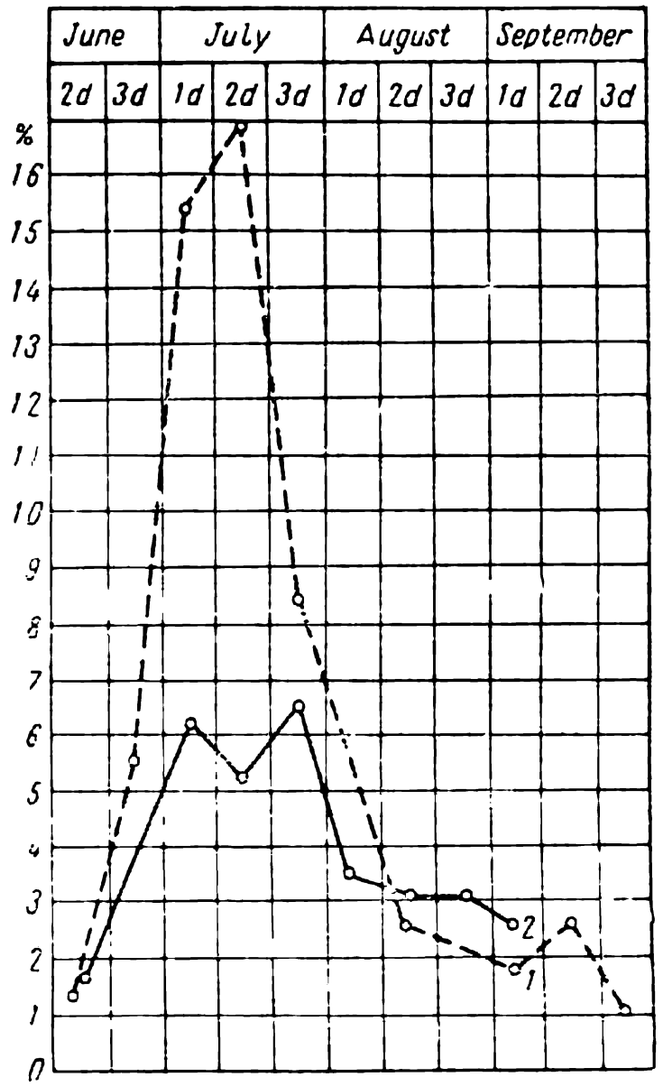
cultivation of areas in immediate proximity to human habitation (Fig. 122) and reclamation of pastureland are also important.

II. Measures aimed at destruction of vectors, such as (1) direct or indirect control of winged vectors of diseases with natural foci, in forms varying with their biological characteristics: (a) control of vectors living or undergoing their metamorphosis on land (sandflies) (Figs. 123, 124); (b) control of vectors depending for their individual development on water reservoirs, and, while in the imago stage, living on land and borne on wings, i.e., leading an aquatic-terrestrial-avian way of life (mosquitoes, black flies, gadflies, midges—Fig. 125); (2) in the case of non-flying terrestrial vectors (ticks) of substantial importance are measures affecting their habitats: (a) treatment of forests with DDT dust manually or from aircraft for destruction of ticks in the forest litter (Fig. 19); (b) treatment of livestock with acaricidal preparations (spraying, bathing in pools, dry treatment with various dusts, etc.) during the feeding of ticks for several days on their agricultural animal hosts; (c) reclamation of pastureland and its rational use. In certain cases, it is helpful to treat livestock with repellent solutions effective against bloodsucking dipterans.

III. Measures aimed to protect man, who is liable to contract a disease from vectors: the use of overalls at work, protective nets designed by the author and treated with repellents (especially with Pervomaisky's and Nizovkin's dry bars used for rubbing




F i g. 123. Decline in the prevalence of *Phlebotomus* sandflies in premises treated with viscid mass for the purpose of controlling sandfly-borne diseases. Turkmenia. According to N. I. Latyshev and A. P. Kryukova, 1941.




F i g. 124. Decline in pappataci fever incidence in 1939 as a result of sandfly control measures taken in 1939 in a southern town, a long-standing focus of this disease. According to E. N. Pavlovsky.

*1*—morbidity rate in 1938; *2*—same in 1939.

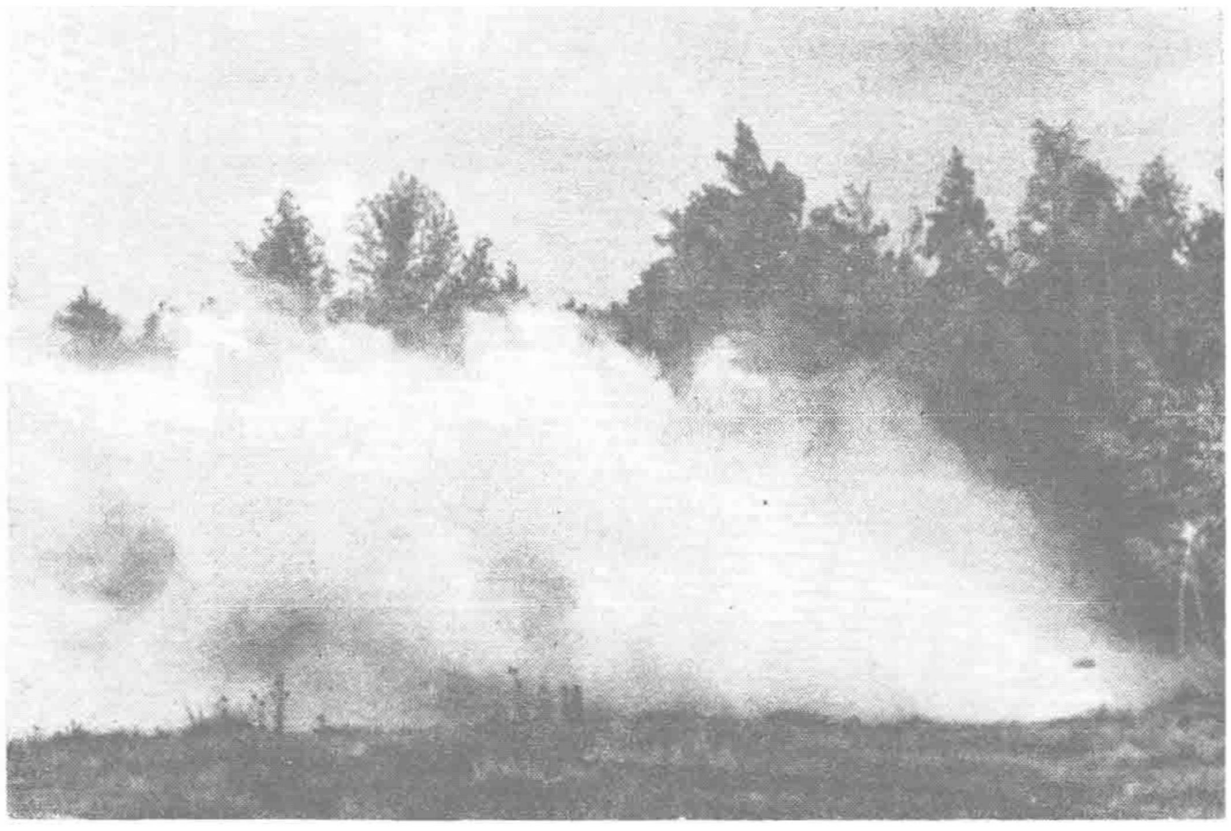


Fig. 125. Fighting punkies with smoke from burning hexachloran smoke-pots.

nets); wearing neatly tucked-in clothes; spreading nets over house windows and doors; destruction of synanthropic rodents and other house pests, and their burrows. In the south where *Ornithodoros* ticks may be present one should avoid staying the night in primitive native structures (Fig. 21), in natural and artificial caves, under an awning in the mountains, close to clay fences known as "duvals" (Fig. 126). In general, it is necessary to take every possible measure to keep off vectors, and to examine the body for removing ticks from the clothes and skin.

All such measures make part of the system of nonspecific prophylaxis of diseases with natural foci. Its application undoubtedly keeps down the risks of infection from vectors in natural foci of disease.

Quite a substantial role is played by the specific prophylaxis of diseases with natural foci by means of special vaccines, such as live vaccines against plague, tularemia and encephalitis. With regard to the latter, an extensive search is underway for new forms of its manufacture.

Since natural foci of diseases are known to occur in combination also, in addition to the manufacture of monovaccines, efforts are made to develop di-, tri- or other polyvaccines in combinations corresponding to those of diseases with natural foci found in different localities.

Attempts have also been made to vaccinate animal donors of disease, in particular goats, whose raw milk used for food may

Fig. 126. An abandoned "duval" (mud fence) in the village of Ab-Kuri in Iran, with *Ornithodoros papillipes* ticks, vectors of tick-borne relapsing fever, taking shelter in its cracks and holes. Topographers who stayed the night near this fence were bitten by infective ticks and all contracted this disease. Drawing from life by F. F. Talyzin.

be the cause of milk-borne encephalitis; these attempts, however, have so far been futile. Therefore, goat milk should necessarily be boiled before it is drunk. Here, one meets with difficulties in overcoming deep-rooted habits by means of health education, which should also be conducted as part of the general health care scheme.

An important element of preventive measures is also the treatment of the external environment, specifically, the territory to be used for children's health centres, young pioneer and sports camps, holiday homes, sanatoria, field work camps, the surroundings of construction projects, sites where natural resources are utilized and settlements on virgin land, if these localities have geographical landscapes suggestive of a particular disease with natural foci, especially of an *occupational* nature. In this case, too, vigorous health education work is required in the form of instructions concerning preventive rules which, however simple, should necessarily be observed every day.

A special problem is the fighting of unhealthful customs and traditional workaday habits likely to facilitate the spread of diseases with natural foci.

On the whole, we are confronted with a task of tremendous complexity and size, yet a perfectly feasible one. The best means to

fulfil it is through joint work of specialists in various fields—biologists, health workers, veterinarians, stock-breeders and other agricultural specialists, teachers, students of local lore and workers of higher schools and specialized institutions (for plague and tularemia control and wider purposes). The integration and coordination of all these forces give the answer to the problem of assanation of the external environment from foci of zoonoses which formed by evolution in times immemorial and have become a hazard to man also. This explains the need to give special attention to zooanthroponoses. Many of them are unknown so far, others require further quest, still others may be brought into being by man himself. All efforts in fighting the adverse forces of nature should be put together to protect public health, which is essential for mankind's further advance along the path of social progress and prosperity.

# BIBLIOGRAPHY


**Adams, M. H.** *Bacteriophages*, Interscience Publ., London, 1959.

**Akiev, A. N., Vologina, I. I.** Seasonal Plague Susceptibility in the Large Sand Rat Rhombomys opimus Licht. In monograph: *Problems of Natural Nidality and Epizootiology of Plague in Turkmenia*, Ashkhabad, 1960.

**Alania, I. I., Dzneladze, M. T., Pushnitsa, F. A., Tinker, I. S., Shiranovich, P. I.** Control of Rat Fleas in Large Cities for Plague Prophylaxis. Comm. II. Experience with Rat Flea Control at Batumi. *Trans. Rostov-on-Don Sci. Res. Inst. Plague Control*, vol. 15, issue 1, 1959.

**Alania, I. I., Dzneladze, M. T., Pushnitsa, F. A., Tinker, I. S., Shiranovich, P. I.** Control of Rat Fleas in Large Cities for Plague Prophylaxis. Comm. IV. Late Results of Rat Flea Control with DDT in Batumi. *Trans Rostov-on-Don Sci. Res. Inst. Plague Control* , vol. 15, issue 1, 1959.

**Alifanov, V. I., Barkova, E. A., Yegorova, L. S., Zakorkina, T. N., Korsh, P. V., Melentyeva, L. A., Ravdonikas, O. V., Trop, I. E., Chulovsky, I. K., Khotetitsky, Y. Y.** Study of Muskrat Epizootics in Natural Foci of Omsk Hemorrhagic Fever in the Omsk Region. In monograph: *Problems of Epidemiology and Prophylaxis of Intestinal and Children's Infections with Natural Foci*, Omsk, 1961.

**Alifanov, V. I., Netsky, G. I., Ravdonikas, O. V., Fyodorov, V. G.** Materials on the Zooparasitological Characteristics of the Natural Focus of Omsk Hemorrhagic Fever in the Tyukalin District of Omsk Region. In monograph: *Problems of Epidemiology and Prophylaxis of Intestinal and Children's Infections with Natural Foci*, Omsk, 1961.

**Amanzhulov, R. S.** The Problem of Simultaneous Vaccination of Man Against Tularemia and Brucellosis. *Health Care in Kazakhstan*, No. 4, 1956.

**Amanzhulov, R. S., Rementsova, M. M.** Simultaneous Vaccination of Man Against Tularemia and Brucellosis. Comm. I. *Microbiol., Epidemiol. and Immunol.*, vol. 29, No. 2, 1958.

**Amosenkova, N. I., Daiter, A. B., Klenov, K. N.** Materials of Field Studies in a Q Fever Focus. *Trans. Leningrad Pasteur Inst. Epidemiol. and Microbiol.*, vol. 23 (Rickettsioses. Diseases with Natural Foci), 1961.

**Anisimova, T. I.** Seasonal Plague Susceptibility in the Gray Rat (*Rattus norvegicus*) at Temperate Latitudes and Its Possible Significance in Plague Epidemiology. Theses of Reports of the Stavropol-in-Caucasus Inst. of Plague Control, 1957.

**Aparin, G. P., Tereshchenko, I. F.** Age Susceptibility of Guinea Pigs and Albino Mice in Experimental Infection with *B. pestis*. *Bul. Irkutsk Inst. Plague Control*, vol. 21, 1959.

**Azarova, A. G., Malishenko, N. I., Tinker, I. S., Shiranovich, P. I.** Control of Rat Fleas in Large Cities for Plague Prophylaxis. Comm. III. Control of Fleas of Synanthropic Rodents in Odessa. *Trans. Rostov-on-Don Inst. Plague Control*, vol. 15, issue 1, 1959.

**Bacot, A.** On the Survival of Bacteria in the Alimentary Canal of Fleas During Metamorphosis From Larva to Adult. *Reports on Plague in India*, vol. II, part 1, 1914.

**Bacot, A. W., Martin, C. J.** Observations on the Mechanism of the Transmission of Plague by Fleas. *J. Hyg.*, Plag. Suppl., III, 1914 (also: *Reports on Plague in India*, vol. II, part 1, 1914).

**Bárdoš, V., Cupkova, E., Sefcovicova, L.** Tahyňa Virus. II. Characteristics of Certain Biological Properties and Preliminary Immunological Classification. *Acta Virologica* (Internat. J., Prague, Russ. Ed.), vol. V, issue 2, 1961.

**Bárdoš, V., Danielová, V.** Tahyňa Virus Isolated from Mosquitoes in Czechoslovakia. *J. Hyg., Epidemiol., Microbiol. and Immunol.* (Prague Russ. Ed.), vol. III, No. 2, 1959.

**Bárdoš, V., Jacobic, J.** Experimental Infection of Swine with Tahyňa Virus. *Acta Virologica* (Internat. J., Prague, Russ. Ed.), vol. V, issue 4, 1961.

**Bárdoš, V., Rosický, B., Vesenjak-Zmijanac, J.** On the Study of the Ecology of Tick-Borne Encephalitis Virus in the Slovenian Alps (Yugoslavia). *J. Hyg., Epidemiol., Microbiol. and Immunol.* (Prague, Russ. Ed.), vol. III, No. 3, 1959.

**Basova, N. N., Volchanetskaya, G. I., Zhitomirskaya, V. M.** Experience with the Study of a Lymphocytic Choriomeningitis Focus (Preliminary Report). *Trans. Kharkov Mechnikov Sci. Res. Inst. Vaccines and Sera*, vol. XX (Virus Infections), 1954.

**Bates, M., Roca-Garcia, A.** Laboratory Studies of the Saimiri-Haemagogus Cycle of Jungle Yellow Fever. *Amer. J. Trop. Med.*, vol. XXV, No. 3, 1945.

**Berg, L. S.** *Physico-Geographical (Landscape) Zones of the U.S.S.R.* Part I. Introduction. The Tundra. The Forest Zone. The Forest-Steppes. 2nd Ed., Leningrad, 1936.

**Berg, L. S.** *Geographical Zones of the Soviet Union*, vol. I, 3rd Ed. Geographical Literature P. H., Moscow, 1947.

**Berg, L. S.** *Geographical Zones of the Soviet Union* , vol. II. Geographical Literature P. H., Moscow, 1952.

**Bezsonova, A. A., Lenskaya, G. N.** Bouillon-Stirring Strains of *B. pestis* (Materials on *B. pestis* Dissociation). *Bull. Microbiol., Epidemiol. and Parasitol.*, vol. VIII, issue 3, 1929.

**Bezsonova, A. A., Lenskaya, G. N., Molodtsova, P. F., Mosolova, O. N.** Communication on Several Facts of Spontaneous Transition of *B. pestis* into *B. pseudotuberculosis rodentium* Pfeiffer'a. *Bull. Microbiol., Epidemiol. and Parasitol.*, vol. XV, issue 2, 1936.

**Blanc, G.** Longue persistance de la virulence du bacille pesteux chez la puce du rat *Xenopsylla cheopis*, conservée morte à sec. *Ann. Inst. Pasteur*, t. 75, No. 6, 1948.

**Blanc, G., Baltazard, M.** Virulence des dejêctions de puces pesteuses. *Ann. Inst. Pasteur*, t. 72, Nos. 5-6, 1946.

**Blaškovič, D.** Notes on the Prophylaxis of Tick-Borne Encephalitis. *J. Hyg., Epidemiol., Microbiol. and Immunol.* (Prague, Russ. Ed.), vol. III, No. 3, 1959.

**Blaškovič, D.** *Koloběh viru su.* Praha, 1963, 115 pp.

**Blagodarny, Y. A.** *Ornithodoros tartakovskyi* Ticks and Steppe *Testudo horsfieldi* Tortoises—Carriers of Pathogenic *Leptospirae* in the Muyunkumy Desert. In collection: *Diseases with Natural Foci and Problems of Parasitology*, issue 3, Kazakh S.S.R. Acad. Press, Alma-Ata, 1961.

*Biological Institutes of the Czechoslovak Academy of Sciences*, Information Collection and Bibliography, 1950-1960, Prague, 1961, 412 pp.

**Borovsky, P. F.** On Saratov Ulcer. *J. Military Med.*, No. 11, 1898, reprinted in *Med. Sci. Uzbekistan*, No. 2, 1927-28.

**Burgdorfer, W.** The Possible Role of Ticks as Vectors of *Leptospirae*. I. Transmission of *Leptospira pomona* by Argasid Tick, *Ornithodorus turicata*, and the Persistence of This Organism in Its Tissues. *Exp. Parasitol.* vol. V, No. 6, 1956.

**Burgdorfer, W.** The Possible Role of Ticks as Vectors of *Leptospirae*. II. Infection of the *Ixodid* Ticks, *Dermacentor andersoni* and *Amblyomma maculatum*, with *Leptospira pomona*. *Exp. Parasitol.*, vol. VIII, No. 5, 1959.

**Bychkov, V. A., Borzenkov, A. K.** Visible Changes in the Gastrointestinal Tract of Fleas Under the Influence of the Presence of *B. pestis*. *Collected Articles on Parasitology, Zool. Museum, U.S.S.R. Acad. Sci.*, vol. II, 1931.

**Combiesco, D., Dimitresco, N.** Survie in vitro de *R. burneti* de la fièvre Q en Roumaine. *Ann. Inst. Pasteur*, t. 76, No. 1, 1949.

**Daiter, A. B., Amosenkova, N. I.** with the participation of **Klenov, K. N.** Role of Ticks of the *Ixodoidea* Superfamily in Q Rickettsiosis. Comm. I. Natural Infection of *Ixodes ricinus L.* ticks with *Rickettsiae burneti*. *Trans. Leningrad Pasteur Inst. Epidemiol. and Microbiol.*, vol. XXIII (Rickettsioses, Diseases with Natural Foci), 1961.

**Daiter, A. B., Amosenkova, N. I.** Role of Ticks of the *Ixodoidea* Superfamily in Q Rickettsiosis. Comm. II. Experimental Infection of the *Ornithodorus papillipes Bir.* Tick with *Rickettsiae burneti*. *Trans. Leningrad Pasteur Inst. Epidemiol. and Microbiol.*, vol. XXIII (Rickettsioses, Diseases with Natural Foci), 1961.

**Demina, G. I., Demin, E. P., Shchekunova, Z. I.** Plague Epizootic Among Pikas in Western Mongolia. *Trans. Irkutsk Inst. Plague Control*, issue 2, Chita, 1961.

**Domoradsky, I. V., Zhovty, I. F., Kraminsky, V. A., Nekipelov, N. V.** Certain Conclusions from the Experience of Work in the Trans-Baikal Plague Focus. *Trans. Irkutsk Inst. Plague Control*, issue 2, Chita, 1961.

**Dravert, I. S., Minakova, L. V., Dorofeyeva, Y. K., Popyvanova, V. M.** Preliminary Data on the Study of Epidemiological Significance of Dairy Cattle in Tick-Borne Encephalitis Prevalence in the Kirov Region. Theses of Reports to the Inter-Regional Sci. Practical Conf. on Infections with Natural Foci, March 13-16, 1961, Tyumen, 1961.

**Dunayeva, T. N.** Experimental Study of Tularemia in Wild Animals (Rodents, Carnivores and Insectivores) as the Basis for the Study of Natural Foci of This Infection. *J. Zool.*, vol. XXXIII, No. 2, 1954.

**Dunayeva, T. N.** Possible Significance of Water in Infection of Animals with Tularemia in Natural Foci. *J. Zool.*, vol. XXXVIII, No. 3, 1959.

**Eskey, C. R., Haas, V. H.** Plague in the Western Part of the United States; Infection in Rodents, Experimental Transmission by Fleas, and Inoculation Tests for Infection. *Publ. Health Rep.*, Aug. 11, 1939 (also: *Publ. Health Serv. Bull.*, No. 254, 1940).

**Fox, I.** The Long Persistence of *R. orientalis* in the Blood and Tissues of Infected Animals. *J. Immunol.*, vol. 59, No. 2, 1948.

**Francis, E.** Sources of Infection and Seasonal Incidence of Tularemia in Man. *Publ. Health Rep.*, No. 52, 1937.

**Fenyuk, B. K., Fyodorov, V. N., Tikhomirova, M. M.** Some Results of the Study of Natural Nidality and Epizootiology of Plague in Turkmenia. In coll.: *Problems of Natural Nidality and Epizootiology of Plague in Turkmenia*, Ashkhabad, 1960.

**Gagarina, A. V., Zimina, V. E., Ravdonikas, O. V.** On Natural Infection of Muskrats with Omsk Hemorrhagic Fever Virus. *Trans. Omsk Inst. Epidemiol., Microbiol., Hyg.*, Coll. of Articles No. 5, Dedicated to the 40th Anniversary of the Great October Socialist Revolution, 1958.

**Gaisky, N. A.** Seasonal Prevalence of Plague in Susliks. *Bull. Microbiol. and Epidemiol.*, vol. V, Nos. 1-2, 1926.

**Gaisky, N. A.** Infection and Immunity in Hibernating Animals. *Bull. Irkutsk Inst. Plague Control*, vol. V, 1944.

**Galindo, P., Trapido, H., Carpenter, S. J.** Observations on Diurnal Forest Mosquitoes in Relation to Sylvian Yellow Fever in Panama. *Amer. J. Trop. Med.*, vol. XXX, No. 4, 1950.

**Garmazova, A. D., Konstantinova, M. A., Yakubovskaya, G. V., Krupko, T. I., Tkachenko, V. I., Gordiyenko, O. Y., Larionova, M. F.** Survival of Causal Agents of Some Highly Virulent Infections in Water. *Trans. Irkutsk Inst. Plague Control*, issue 2, Chita, 1961.

**Geigy, R., Herbig, A.** Erreger und Ueberträger tropischer Krankheiten. *Acta Tropica*, Suppl. 6, Basel, 1955.

*Geobotanical Map of the U.S.S.R*, scale 1 : 4,000,000, Ed. by E. M. Lavrenko and V. B. Sochava, Moscow-Leningrad, 1954 (1955).

*Geography of Terrestrial Animal Population and Methods for Its Study*, Ed. by A. N. Formozov, U.S.S.R. Acad. Press, Moscow, 1959.

**Gilmanova, G. H., Gubaidullin, Y. S.** Dissemination of Tick-Borne Encephalitis Virus Through Goat Milk in Natural Foci in the Tatar S.S.R. *Trans. Kazan. Sci. Res. Inst. Epidemiol. and Hyg.*, issue 4, 1959.

**Glushchenko, P. A., Gutsevich, A. V., Dudkina, M. S.** Study of Mosquitoes as Vectors of the Lymphocytic Choriomeningitis Virus in Western Ukraine. *Trans. U.S.S.R. Acad. Sci.*, vol. 113, No. 5, 1957.

**Goar, S. A.** Vampires as Vectors of Trypanosomiases. In monograph: *Problems of General Zoology and Medical Parasitology*, Med. Lit. P. H., Moscow, 1962.

**Golov, D. A. and Ioff, I. G.** Suslik Fleas as Reservoirs of Plague Infection in Winter. *Bull. Microbiol. and Epidemiol.*, vol. V, No. 4, 1926.

**Golov, D. A., Ioff, I. G.** Influence of Various Conditions on the Survival of *B. pestis* in Fleas at Different Stages of Their Development. *Proc. 1st All-Russia Conf. on Plague Control*, Saratov, 1928.

**Golov, D. A., Ioff, I. G.** Role of Fleas of Rodents in the South-Eastern U.S.S.R. in the Epidemiology of Plague. *Proc. 1st All-Russia Conf. on Plague Control*, Saratov, 1928.

**Gorchakovskaya, N. N., Preobrazhenskaya, N. K., Dobrynina, L. I., Bondaryeva, M. P., Toshigin, Y. V., Yevdokimova. P. T., Peresypkina, A. V.** Spring Treatment of Forests from Aircraft for Control of Tick-Borne Encephalitis Vectors and the Duration of the Tick Destruction Effect in Acaricide Treatment of Natural Vector Habitats. Theses of Reports to the Interregional Sci. Practical Conf. on Diseases with Natural Foci. Krasnoyarsk, 1957.

**Grešíková,** M. Isolation of Tick-Borne Encephalitis Virus from the Blood and Milk of Subcutaneously Infected Sheep. *Acta Virologica* (Internat. J., Prague. Russ. Ed.), vol. II, issue 2, 1958.

**Grešíková-Kohútová, M., Albrecht, P.** Experimental Pathogenicity of the Tick-Borne Encephalitis Virus for the Green Lizard, *Lacerta viridis* (Laurenti 1768). *J. Hyg., Epidemiol., Microbiol. a. Immunol.*, vol. III, No. 3. Prague, 1959.

**Gutsevich, A. V.** Insects Spreading Human Diseases. *Nature*. No. 3, 1962.

**Gutsevich, A. V.** with the participation of **Grachev, P. E., Skrynnik, A. N., Pervomaisky, G. S.** Materials on the Study of Bloodsucking Dipterans (Punkies) in the Trans-Baikal Area. *Trans. Kirov. Acad. Military Med.*, vol. XIX, 1939.

**Haddow, A. J., Davies, C. W., Walker, A. J.** O'nyong-nyong Fever: an Epidemic Virus Disease in East Africa. I. Introduction. *Trans. Roy. Soc. Trop. Med. a. Hyg.*, vol. LIV, No. 6, 1960.

**Hoeden, J., van der.** Leptospiral Infections in Hedgehogs. *J. Inf. Dis.*, vol. 103, 1958.

**Hoogstraal, H., Kaiser, M. N., Traylor, M. A., Guindy, E., Gaber, S.** Ticks (*Ixodidae*) on Birds Migrating from Europe and Asia to Africa, 1959-1961. *Bull. World Health Org.*, vol. XXVIII, 1963.

*Human Diseases with Natural Foci.* Ed. by Acad. Pavlovsky, Moscow, 1963 (Translation from Russ. Ed. Moscow Med. Literature P. H., 1960, 326 pp.).

**Imanov, E. D.** Prevalence of Q Rickettsiosis in the Kirghiz S.S.R. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXXII, No. 10, 1961.

**Ioff, I. G.** *Problems of Ecology of Fleas in Relation to Their Epidemiological Significance.* Ordzhonikidze Territorial P. H., Pyatigorsk, 1941.

**Iroveč, O.** Toxoplasmosis and Pneumocystosis as Anthropozoonoses. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXXII, No. 10, 1961.

**Kalabukhov, N. I., Ladygina, N. M.** Origination of Ecologo-Physiological Characteristics in Mammals Under the Influence of the External Environment. *J. Zool.*, vol. XXXII, No. 2, 1953.

**Kalacheva, N. F.** Experimental Study of Complex Vaccination Against Plague and Tularemia. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXIX, No. 9, 1958.

**Karakulov, I. K., Amanzhulov, S. A., Borisov, V. D.** On the Study of Q Fever in Western Kazakhstan. In coll.: *Diseases with Natural Foci and Problems of Parasitology.* issue 3, Kazakh Acad. Press, Alma-Ata, 1961.

**Kashkadamov, V. P.** Plague in Manchuria in Autumn. 1903. The U.S.S.R. Soc. Hyg., Forensic and Practical Med., July, 1906.

**Khakhina, Z. D., Somova, A. G., Silich, V. A., Polyakov, I. I., Gerasyuk, L. G.** Experimental Mixed Infection. Q Fever and Brucellosis. Comm. III. Pathomorphology of Mixed Infection. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXXI, No. 2, 1960.

**Khrustselevsky, V. P.** Regularities of Changes in Brandt's Field Vole Prevalence in the South-East Trans-Baikal Region. *Bull. Irkutsk Inst. of Plague Control*, vol. XIII, 1954.

**Khundanov, L. E., Klets, E. I., Shkurko, E. D.** Experience with the Production of Bivalent Serum Against Plague and Anthrax. *Trans. Irkutsk Inst. of Plague Control*, issue 2, Chita, 1961.

**Kiselev, R. I.** Certain Problems of Epidemiology of Smallpox-Like Rickettsiosis. *Trans. Kharkov Mechnikov Sci. Res. Inst. of Vaccines and Sera*, vol. XX (Virus Infections), 1954.

**Kislyakova, L. N., Levi, M. I.** Experimental Study of the Mechanism of Transmission, Term of Carrier State and Discharge of Lymphocytic Choriomeningitis Virus in House Mice. *Trans. Kharkov Mechnikov Sci. Res. Inst of Vaccines and Sera*, vol. XX (Virus Infections), 1954.

**Klets, E. I., Kolesnik, R. S., Vyborov, G. P.** Experimental Data on the Stability of Immunity to Brucellosis Following Vaccination with an Associated Vaccine Against Brucellosis, Tularemia, and Plague. *Trans. Irkutsk Inst. of Plague Control*, issue 2, Chita, 1961.

**Klets, E. I., Kolesnik, R. S., Skalon, T. G., Potapova, E. P.** The Problem of Immunization with an Associated Vaccine Against Plague, Tularemia and Brucellosis by the Skin Method. *Trans. Irkutsk Inst. of Plague Control*, issue 2, Chita, 1961.

**Klets, E. I., Kudinova, Z. S., Kolesnik, R. S., Pletnikova, G. P.** The Problem of Susceptibility of Steppe Rodents to Low Virulent Microbe Strains Isolated in the Trans-Baikal Region. *Trans. Irkutsk Inst. of Plague Control*, issue 2, Chita, 1961.

**Klets, E. I., Khrustselevsky, V. P., Kolesnik, R. S., Kudinova, Z. S., Olkova, N. V., Smirnova, L. A.** Susceptibility of Tarabagans and Long-Tailed Susliks to Experimental Plague. Theses of Reports to a Conf. at the Irkutsk Inst. of Plague Control, issue 1, 1955.

**Klets, E. I., Shchekunova, Z. I.** The Term of *B. pestis* Survival in Certain Objects of the External Environment. *Trans. Irkutsk Inst. of Plague Control*, issue 2, Chita, 1961.

**Klets, E. I., Shchekunova, Z. I., Padalko, Z. F.** Susceptibility of Certain Rodent Species of the Maritime Territory to Experimental Plague. *Bull. Irkutsk Inst. of Plague Control*, vol. 21, 1959.

**Kolesnik, R. S., Pletnikova, G. P.** Characteristics of Experimental Plague in the Daur Suslik. *Bull. Irkutsk Inst. of Plague Control*, vol. 21, 1959.

**Kolomakin, G. A.** Dogs as Agents in Transmission of Brucellosis from Hares to Farm Animals. In coll.: *Diseases with Natural Foci and Problems of Parasitology*, issue 3, Kazakh Acad. Press, Alma-Ata, 1961.

**Kondrashkin, G. A.** Modern Problems of Natural Nidality of Tularemia in the U.S.S.R. Theses of Reports to the Sci. Conf. on Natural Foci of Disease and Epidemiology of Highly Virulent Infections, Jan. 25-Feb. 2, 1957, Saratov, 1957.

**Kornilova, A. L.** Domestic Animals as a Source of Infection in Listerellosis. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXVII, No. 9, 1956.

**Krasnik, F. I.** The Problem of Survival of *Rickettsiae prowazeki* upon Recovery from Typhus (Experimental Study). *Trans. Leningrad Pasteur Inst. of Epidemiol. and Microbiol.*, vol. XXIII (Rickettsioses. Diseases with Natural Foci), 1961.

**Krepkogorskaya, T. A.** Infection of the Large Gerbil (*Rhombomys opimus*) with Kazakhstan-II-type Pathogenic *Leptospira*. *Bull. Kazakh Acad. of Sci.*, No. 5, 1954.

**Krepkogorskaya, T. A., Rementsova, M. M.** Isolation of Leptospira Strains from *Dermacentor marginatus S.* Ticks Captured on Neat Cattle. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXVIII, No. 2, 1957.

**Kucheruk, V. V.** The Role of Various Mammals in Plague Epizootics and Origination of Human Diseases in the Mongolian-Trans-Baikal Endemic Focus. *J. Zool.*, vol. XXXV, No. 5, 1945.

**Kumm, H. W.** Yellow Fever Transmission Experiments with South American Bats. *Ann. Trop. Med.*, vol. XXVI, 1932.

**Lavrovsky, A. A.** Distribution of Certain Animal Species and Changes in Their Prevalence Areas in Connection with the Current Regression of the Caspian Sea. In monograph: *Geography of the Terrestrial Animal Population and Methods for Its Study*. Ed. by A. N. Formozov. U.S.S.R. Acad. Press, Moscow, 1959.

**Larionova, M. F., Solodkaya, A. D., Pletnikova, G. P., Savchenko, A. A., Tarasov, N. S., Shvedko, L. P., Maksimova, E. D., Dubovik, I. M.** Plague in Rodents in 1960 in the Borzin District of Chita Region. *Trans. Irkutsk Inst. of Plague Control*, issue 2, Chita, 1961.

**Latyshev, N. I., Kryukova, A. P.** Epidemiology of Cutaneous Leishmaniasis. Cutaneous Leishmaniasis as a Zoonosis of Wild Rodents in Turkmenia. *Trans. Kirov Acad. Military Med.*, vol. XXV (Coll. Works Dedicated to the 30th Anniversary of the Scientific, Pedagogical and Public Activities of Acad. E. N. Pavlovsky), 1941.

**Latyshev, N. I., Kryukova, A. P.** Experience with Determination of Sandflies Flight Range in a Reclaimed Desertland. *J. Zool.*, vol. XX, No. 3, 1941.

**Legkodimova, K. V., Somov, G. P.** Materials on the Clinical Characteristics, Etiology and Epidemiology of Tick-Borne Typhus in the Kalinin District of the Maritime Territory. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXXII, No. 10, 1961.

**Leibenzon, A. S.** Materials on the Epidemiology and Clinical Picture of Non-Icteric Leptospirosis in the Eastern-Kazakhstan Region. In coll.: *Diseases with Natural Foci and Problems of Parasitology*, issue 3, Kazakh Acad. Press, Alma-Ata, 1961.

**Lenskaya, G. N.** The Results of Studies of the Variability of *B. pestis*. *J. Microbiol., Epidemiol. and Immunol.*, vol. 18, No. 2, 1947.

**Leshkovich, L. I.** Studies of Tarabagan Hibernation. *Bull. Irkutsk Inst. of Plague Control*, vol. 8, 1950.

**Letov, L. S.** The Structure of Tarabagan Burrows. *Bull. Irkutsk Inst. of Plague Control*, vol. 8, 1950.

**Levi, M. I., Gusev, V. M., Kislyakova, L. N., Volchanetskaya, G. I., Kiselev, R. I.** Natural Nidality of Lymphocytic Choriomeningitis. *Coll. Works of Kharkov Mechnikov Sci. Res. Inst. of Vaccines and Sera*, vol. XX (Virus Infections), 1954.

**Levi, M. I., Kiselev, R. I., Chuyeva, G. I., Kislyakova, L. N.** On the Epidemiology of Smallpox-Like Rickettsiosis. *Coll. Works of the Kharkov Mechnikov Sci. Res. Inst. of Vaccines and Sera*, vol. XX (Virus Infections), 1954.

**Levi, M. I., Kislyakova, L. N., Gusev, V. M., Volchanetskaya, G. I.** Study of Rodents and Their Ectoparasites in Foci of Lymphocytic Choriome-

ningitis. *Coll. Works of the Kharkov Mechnikov Sci. Res. Inst. of Vaccines and Sera*, vol. XX (Virus Infections), 1954.

**Levkovich, E. N.** The Current Views of the Problem of Tick-Borne Encephalitis. In coll.: *Problems of Medical Virology*, issue 6 (Neuroinfections), Moscow, 1959.

**Lisitsyn, A. A., Kucherov, N. M., Kontsov, V. V., Demyashev, M. P., Kukin, V. M., Skardov, M. M.** The Employment of Aviation for Suslik Control in the Territory of the Volga-Ural Natural Focus of Plague. In coll.: *Diseases with Natural Foci and Problems of Parasitology*, issue 3, Kazakh Acad. Press, Alma-Ata, 1961.

**Lisitsyn, A. A., Yakovlev, M. G.** Preliminary Results and Prospects for Rodent Control in the Volga-Ural Natural Focus of Plague. In coll.: *Diseases with Natural Foci and Problems of Parasitology*, issue 3, Kazakh Acad. Press, Alma-Ata, 1961.

**Maksimov, A. A.** Natural Foci of Tularemia in the U.S.S.R. U.S.S.R. Acad. Press, Moscow-Leningrad, 1960.

*Manual of Microbiology, Clinical Manifestations and Epidemiology of Infectious Diseases*, vol. 1, Moscow, 1962.

*Materials of the Plenary Scientific Conference on Diseases with Natural Foci Held Feb. 15-17, 1963*, Tyumen, 1963, 220 pp.

*Materials of the 3rd Congress of the U.S.S.R. Geographical Society on the Problem "General Theory and Practical Application of the Method of Landscape Study"*. Leningrad, 1960.

**McCoy, G. W.** A Plague-Like Disease of Rodents. *Publ. Health Bull.*, No. 43, 1911.

**McCoy, G. W., Chapin, C. W.** *Bacterium tularense*—the Cause of a Plague-Like Disease of Rodents. *Publ. Health Bull.*, No. 53, 1912.

**Mironov, N. P.** Changes in the Rodent Prevalence Areas as a Factor Contributing to Formation of Natural Foci of Certain Infections in the South-East of the European Part of the Russian Federation. In monograph: *Geography of the Terrestrial Animal Population and Methods for Its Study*, Ed. by A. N. Formozov, U.S.S.R. Acad. Press, Moscow, 1959.

**Mironov, N. P., Tinker, I. S., Shiranovich, P. I., Shishkin, A. K.** Regularities of Plague Epizootics in the North-Western Caspian Focus. Natural Nidality and Epidemiology of Highly Virulent Infections. *Proc. Inter-Inst. Sci. Conf. Jan. 25-Feb. 2, 1957*, Saratov, 1959 (1960).

**Mitov, A., Yankov, N., Ivanov, I.** New Data on Leptospirosis in Bulgaria. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXXII, No. 10, 1961.

**onchadsky, A. S.** Activity of Mosquitoes in Nature at Night and Its Epidemiological Characteristics. *J. Zool.*, vol. XXXII, No. 5, 1953.

**Monchadsky, A. S.** Attacks of Mosquitoes on Man in the Seaside Regions of the Volga Delta. *Parasitol. Coll., Inst. Zool., U.S.S.R. Acad. Sci.*, vol. XVI, 1956.

**Moshkovsky, S. D., Demina, N., Nosina, V. D., Pavlova, E., Livshits, I., Pels, G., Rubtsova, V.** Pappataci Fever Virus in Sandflies Hatched from Eggs Deposited by Infected Females. *Med. Parasitol. and Parasitic Diseases*, vol. VI, No. 6, 1937.

**Moshkovsky, S. D., Nosina, V. D.** Staining of Sandflies (*Phlebotomus*) as a Method for Study of Certain Aspects of Their Biology and Ecology. *Med. Parasitol. and Parasitic Diseases*, vol. II, No. 6, 1933.

**Moskvin, I. A.** Spontaneous Infection of Birds with Tick-Borne (Spring-Summer) Encephalitis. Theses of Reports to the 2nd Conf. on Parasitol. (November, 1940, Leningrad), U.S.S.R. Acad. Press, Moscow-Leningrad, 1940.

*Natural Foci of Human Infections. Jerusalem*, 1963. (Translation from Russ., Ed. by Acad. E. N. Pavlovsky. Med. Literature P. H., Moscow, 1960. 326 pp.).

**Naumov, N. P., Zhuchayev, A. A., Arslanova, A. K., Zhuchayeva, A. F., Varshavsky, S. N., Shilov, M. N., Besedin, B. D., Podlessky, G. I., Krylova, K. T., Shilova, E. S., Komardina, M. G.** Basic Results of the Epizootiological Study of the Aral Portion of the Central Asian Plain Focus in the Period from 1946 to 1956. Theses of Reports Sci. Conf. on Natural Nidality and Epidemiology of Highly Virulent Infections, Jan. 25-Feb. 2, 1957, Saratov, 1957.

**Naumov, N. P., Zhuchayev, A. A., Varshavsky, S. N., Arslanova, A. K., Shilov, M. N., Besedin, B. D., Podlessky, G. I., Krylova, K. T., Shilova, E. S., Komardina, M. G., Zhuchayeva, A. F.** Conditions of Existence and Important Epizootiological Peculiarities of Natural Focus of Plague in the Central Asian Plain. Natural Nidality and Epidemiology of Highly Virulent Infections. *Coll. Articles Inter-Inst. Sci. Conf., Jan. 25-Feb. 2, 1957*, Saratov, 1959 (1960).

**Nekipelov, N. V.** Certain Observations on the Ungurian Field Vole (*Microtus ungurensis Kast.*). *Bull. State Inst. Plague Control in Siberia and the Far East*, vol. III, 1936.

**Nekipelov, N. V.** Factors Influencing the Prevalence of Marmots and Susliks in the Steppes of the South-West Trans-Baikal Region. Theses of Reports to a Conf. Irkutsk Inst. of Plague Control, issue 1, 1955.

**Nekipelov, N. V.** Seasonal Activity and Contacts of Trans-Baikal Rodents. *Bull. Irkutsk Inst. of Plague Control*, vol. X, 1952.

**Nekipelov, N. V.** The Climate in the South-East Trans-Baikal Region and Historical Survey of Plague Epizootics in Relation to Climatic Changes. *Bull. Irkutsk Inst. of Plague Control*, vol. XV, 1957.

**Nikitina, N. A., Kucheruk, V. V., Rozhkov, A. A.** Age, Sexual, and Seasonal Differences in the Sensitivity of the Little Marmots to Zinc Phosphide. *Problems of Regional, General and Exp. Parasitol. and Med. Zool.*, vol. IX, 1955.

**Novokreshchenova, N. S.** Ecological Foundations of Fleas Control in Burrows of Little Marmots and Large Gerbils. Summary of Master's Thesis, Leningrad, 1962.

**Olkova, N. V., Smirnova, L. A.** Seasonal Susceptibility of Tarabagans and Long-Tailed Susliks to Experimental Plague. *Bull. Irkutsk Inst. of Plague Control*, vol. XXI, 1959.

**Olsufyev, N. G.** Landscape Types of Tularemia Foci in the Middle Belt of the Russian Federation. *J. Zool.*, vol. XXVI, No. 3, 1947.

**Olsufyev, N. G.** Natural Nidality of Erysipeloid (Erysipelas of Swine) and Listerellosis. In monograph: *Infectious Diseases with Natural Foci in Kazakhstan*, issue 2, Kazakh Acad. Press, Alma-Ata, 1954.

**Olsufyev, N. G.** Worldwide Prevalence of Tularemia, Its Epidemiology and Prophylaxis. Natural Nidality and Epidemiology of Highly Virulent Infections. *Proc. Inter-Inst. Sci. Conf. Jan. 25-Feb. 2, 1957*, Saratov, 1959 (1960).

**Olsufyev, N. G., Dunayeva, T. N.** Epizootiology (Natural Nidality) of Tularemia. In monograph: *Tularemia*, Ed. by N. G. Olsufyev and G. P. Rudnev, Med. Literature P. H., Moscow, 1960.

**Olsufyev. N. G., Yemelyanova. O. S.** Detection of Listerellosis Infection in Wild Rodents, Insectivorous and *Ixodes* Ticks. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXII, No. 6, 1951.

**Olsufyev. N. G., Yemelyanova, O. S.** Mixed Epizootic of Tularemia, Listerellosis and Streptococcic Infection Among Common Voles in Wintertime. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXV, No. 2, 1954.

**Olsufyev. N. G., Kucheruk, V. V., Dunayeva, T. N., Rubina, M. A.** Experience with the Study of Winter Epizootics of Tularemia in Common Voles in Stacks of Straw and Hay. Comm. I. Tularemia Epizootics Originating in Floodland-Type Natural Foci. *Problems of Regional, General and Exp. Parasitol. and Med. Zool.*, vol. IX, 1955.

**Pavlovsky, E. N.** A Course in Human Parasitology. Med. Literature P. H., Moscow-Leningrad, 1934.

**Pavlovsky, E. N.** General Problems of Parasitology and Zoology. U.S.S.R. Acad. Press, Moscow-Leningrad, 1961.

**Pavlovsky, E. N.** Factors Responsible for the Existence of a Natural Focus of Disease in Its Characteristic Territory. *J. Zool.*, vol. XLII, No. 3, 1963.

**Pavlovsky, E. N., Skrynnik. A. N.** Experimental Analysis of the Significance of Different Phases of *Ornithodorus papillipes* Metamorphosis in Transmission of Tick-Borne Relapsing Fever Spirochetes. *Parasitol. Coll., Inst. Zool., U.S.S.R. Acad. of Sci.*, vol. XIV, 1952.

**Pavlovsky, E. N., Solovyov, V. D.** Experimental Study of the Circulation of Tick-Borne Encephalitis Virus in the Vector Tick (*Ixodes persulcatus*). Arch. Biol. Sci., vol. LIX, issue 2, Nos. 7-8, 1940.

**Pavlovsky, E. N.** *Works on Experimental Parasitology.* Moscow-Leningrad, U.S.S.R. Acad. Press, 1963, 274 pp.

**Pastukhov, B. N.** Epizootic Status of Natural Foci of Plague in the U.S.S.R. in 1954-1956 and Analysis of Measures Implemented. Natural Nidality and Epidemiology of Highly Virulent Infections. *Proc. Inter-Inst. Sci. Conf. Jan. 25-Feb. 2, 1957*, Saratov, 1959 (1960).

**Petrishcheva, P. A.** *Field Methods for the Study of Sandflies and Sandfly Control.* Med. Literature P. H., 1954.

**Petrishcheva, P. A., Alymov, A. Y.** Transembryonal Transmission of Pappataci Fever Virus by Sandflies. *Arch. Biol. Sci.*, vol. LIII, issue 1, 1939.

**Petrov, V. P.** Epidemiology of Pappataci Fever in Relation to Sandfly Biology. Tashkent, 1929 (Report of Standing Commission for Study of Malaria Mosquitoes at Zoology Museum of U.S.S.R. Academy of Sciences).

**Petrov, V. G., Dunayeva, T. N.** Relationship Between Infection of *Ixodes* Ticks and the Course of Tularemia in Animal Donors. *Problems of Regional, General and Exp. Parasitol. and Med. Zool.*, vol. XI, 1955.

**Petrov, V. G., Olsufyev, N. G.** Reproduction of *Bact. tularense* in *Dermacentor pictus* Ticks During Their Metamorphosis. *Problems of Regional, General and Exp. Parasitol. and Med. Zool.*, vol. VIII, 1953.

**Philip, C.** Comments on the Name of the Q Fever Organism. *Publ. Health Rep.*, vol. LXIII, No. 2, 1948.

**Pletnikova, G. P.** Organization of Plague Control Measures in the Trans-Baikal Region. *Trans. Irkutsk Inst. of Plague Control*, issue 2, Chita, 1961.

**Polyakov, I. I., Somova, A. G., Silich, V. A., Khakhina, Z. D., Gerasyuk, L. G.** Experimental Mixed Infection with Q Fever and Brucellosis. Comm. II. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXX, No. 3, 1959.

**Pomerantsev, B. I., Serdyukova, G. V.** Ecological Observations on Ticks of the Family *Ixodidae*, Vectors of Spring-Summer Encephalitis in the Far East. *Parasitol. Coll., Inst. Zool., U.S.S.R. Acad. Sci.*, vol. IX, 1947 (1948).

*Problems of General Zoology and Medical Parasitology*, Ed. by Prof. P. G. Sergiyev et al., Moscow, Med. Literature P. H., 1962. 610 pp.

*Problems of Infectious and Invasive Diseases*, issue 2, *Trans. Kishinev State Med. Inst.*, vol. XIV, 1961.

**Quan, S. F., Kartman, L., Prince, F. M., Miles, V. I.** Ecological Studies of Wild Rodent Plague in the San Francisco Bay Area of California. IV. The Fluctuation and Intensity of Natural Infection with *Pasteurella pestis* in Fleas During an Epizootic. *Amer. J. Trop. Med. a. Hyg.*, vol. IX, 1960.

**Rall, Y. M.** *Lectures on Plague Epizootiology*, Stavropol, 1958.

**Rementsova, M. M.** Additional Sources of Brucellosis Infection. In coll.: *Diseases with Natural Foci and Problems of Parasitology*, issue 3, Kazakh Acad. Press, Alma-Ata, 1961.

**Rementsova, M. M.** *Brucellosis of Wild Animals*, Alma-Ata, Kazakh Acad. Press, 1962, 272 pp.

**Roubaud, E., Stefanopoulo, G.** Recherches sur la transmission par la voie stégomyienne du virus neurotrope murin de la fièvre jaune. *Bull. Soc. Pathol. exot.*, t. XXVI, No. 2, 1933.

**Ryabov, N. I.** Materials on the Biology of the Trans-Baikal Marmot (*Marmota sibirica Radde*) in Wintertime. *J. Zool.*, vol. XXVII, No. 3, 1948.

**Sardar, E. A.** Susceptibility of the Social and Common Field Voles to Plague Infection. *Trans. Caucasus and Trans-Caucasia Inst. of Plague Control.* issue 1, Stavropol, 1956.

**Sakhnovskaya, G. K.** Tetanus Prevalence and Contamination of Soils with *Bac. tetani* in Western Ukraine. Summary of Master's Thesis, Lvov, 1959.

**Schlossberger, H., Langbein, H.** Übertragung von *Leptospira icterohaemorrhagiae* durch *Ornithodorus moubata. Z. Immunitätsforsch*, Bd. CIX, 1952.

**Shapiro, D. M., Krepkogorskaya, T. A.** Leptospirosis in Eastern Kazakhstan. In coll.: *Diseases with Natural Foci and Problems of Parasitology*, issue 3. Kazakh Acad. Press, Alma-Ata, 1961.

**Sharets, A. S., Berendyayev, S. A., Krasnikova, L. V., Tristan, D. F.** Epizootiological Efficacy of a Single Marmots Control Operation. *Trans. Central Asian Res. Inst. of Plague Control*, issue 4, Alma-Ata, 1958.

**Shiranovich, P. I., Shishkin, A. K., Ivanov, I. K., Zinin, P. I., Koptsev, V. V., Timofeyev, B. F.** Experience with Simultaneous Destruction of Wild Rodents and Their Fleas in Occupational Surroundings. Natural Nidality and Epidemiology of Highly Virulent Infections. *Proc. Inter-Inst. Sci. Conf. Jan. 25-Feb. 2, 1957*, Saratov, 1959 (1960).

**Shiryayev, D. T.** Experimental Data on Susceptibility of House Mice to Plague Infection. Theses of Reports to the Sci. Conf. on Natural Nidality and Epidemiol. of Highly Virulent Infections, Jan. 25-Feb. 2, 1957, Saratov, 1957.

**Shishkin, A. K.** The 25th Anniversary of the Rostov-on-Don Scientific Research Institute of Plague Control. *Trans.*, vol. XV, issue 1, 1959.

**Shishkin, A. K.** Experience with the Eradication of Natural Foci of Plague in the North-Western Caspian Region. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXXII, No. 5, 1961.

**Shur, R. M.** Some Data on the Comparative Study of Biological Properties of Lymphocytic Choriomeningitis and Chorioencephalitis Virus Strains. *Trans. Kharkov Mechnikov Res. Inst. of Vaccines and Sera*, vol. XX (Virus Infections), 1954.

**Shutyayev, N. A.** Survival of *Leptospira* in Water. In coll.: *Diseases with Natural Foci and Problems of Parasitology*, issue 3, Kazakh Acad. Press, Alma-Ata, 1961.

**Soběslavský, O., Syrůček, L.** Transovarial Transmission of *Coxiella burneti* in the Domestic Fowl *Gallus gallus domesticus*. *J. Hyg., Epidemiol., Microbiol. and Immunol.* (Prague, Russ. Ed.), vol. III, No. 4, 1959.

**Solovyov, V. D.** Mammals and Birds as Reservoirs of Seasonal Encephalitis Virus in Nature. *J. Microbiol., Epidemiol. and Immunol.*, vol. XII, No. 4, 1941.

**Solovyov, V. D.** Reservoir of Spring-Summer Encephalitis Virus in Nature. *Trans. Kirov Acad. of Military Med.*, vol. XXV (Coll. Works Dedicated to the 30th Anniversary of the Scientific, Pedagogical and Public Activities of Acad. E. N. Pavlovsky), 1941.

**Solodkaya, A. D., Kolesnik, R. S., Pletnikova, G. P.** Susceptibility of Tarabagans to Plague During Winter Hibernation. *Trans. Irkutsk Inst. of Plague Control*, issue 2, Chita, 1961.

**Soloshenko, I. Z.** The Role of Bloodsucking Arthropods in Transmission of Vasilyev-Weil's Disease. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXIX, No. 1, 1958.

**Somova, A. G., Silich, V. A., Polyakov, I. I., Khakhina, Z. D., Gerasyuk, L. G.** Experimental Mixed Infection with Q Fever and Brucellosis. Comm. I. Characteristics of the Course of Q Rickettsiosis. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXX, No. 3, 1959.

**Suvorov, S. V., Volferts, A. A., Voronkova, M. M.** Plague-Like Lymphadenitis in the Astrakhan Region. *Bull. Microbiol., Epidemiol. and Parasitol.*, vol. VIII, issue 3, 1928.

*Symposium on Theoretical Questions of Natural Foci of Diseases. Preliminary Papers*, vol. I and II. Prague, 1963.

**Tarasevich, I. V.** The Study of Q Fever Vectors in Focus C. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXVI, No. 6, 1955.

**Tarasevich, I. V.** *Hyalomma plumbeum plumbeum* and *Rhipicephalus bursa* Ticks—Reservoirs and Vectors of *Rickettsiae burneti* in a Q Fever Focus in the Crimea. Summary of Thesis, Moscow, 1956.

*Tick-Borne Encephalitis and Virus Hemorrhagic Fevers.* Proc. Sci. Conf., Omsk, 1963, 429 pp.

**Timofeyeva, L. A., Zhovty, I. F., Nekipelov, N. V., Busoyedova, N. M., Golovacheva, V. Y., Dubovik, I. M., Dubovik, V. I., Zhivolyapina, R. R., Leontyev, L. N., Petukhova, O. M., Timofeyeva, A. A., Shvedko, L. P.** Search for Plague and Other Epizootic Diseases of Rodents in the Trans-Baikal Focus of Plague (Comm. I). *Bull. Irkutsk Inst. of Plague Control*, vol. XV, 1957.

**Tinker, I. S., Zenkevich, A. M.** Certain Observations on the Ecology of Suslik Fleas in Relation to Their Role in Plague Epidemiology. *Parasitol. Coll., Inst. Zool., U.S.S.R. Acad. Sci.*, vol. IV, 1934.

**Tinker, I. S., Kalabukhov, N. I.** Changes in Plague Susceptibility of Susliks Depending on Age and Sex Differences. *Bull. Microbiol., Epidemiol. and Parasitol.*, vol. XIII, issue 4, 1934.

**Tiflov, V. E.** The Role of Bacteriophage in the Process of Elimination of Plague Infection in Fleas. *Bull. Microbiol., Epidemiol. and Parasitol.* Coll. of Sci. Works Dedicated to the 25th Anniv. of the "Microbe" Inst. Supplement. Theses of Reports, Saratov, 1944.

**Tokarevich, K. N.** The Current Status and Further Problems of the Study of Infections with Natural Foci in the North-West. *Trans. Leningrad Pasteur Inst. of Epidemiol. and Microbiol.*, vol. XXIII (Rickettsioses. Diseases with Natural Foci), 1961.

**Tokarevich, K. N., Vasilyeva, L. D., Amosenkova, N. I., Daiter, A. B., Popova, E. M., Bessonova, M. A., Klenov, K. N.** Epidemiological Characteristics of a Local Focus of Q Rickettsiosis. *Trans. Leningrad Pasteur Inst. Epidemiol. and Microbiol.*, vol. XXIII (Rickettsioses. Diseases with Natural Foci), 1961.

**Toporkov, M. F.** The Rate of Relapses in Patients with Acute and Chronic Dysentery in Cyclic Sulpha-Drug Therapy. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXXII, No. 10, 1961.

*Transactions of the Irkutsk Institute of Plague Control*, issue 4, 1962, 226 pp.

**Traub, E.** Factors Influencing the Persistence of Choriomeningitis Virus in the Blood of Mice After Clinical Recovery. *J. Exp. Med.*, vol. LXVIII, No. 2, Aug. 1, 1938.

**Tregubova, N. G.** Erysipelas and Listerellosis of Ducks. *Vet. Med.*, No. 10, 1961.

*Tularemia*, Ed. by N. G. Olsufyev and G. P. Rudneva, Med. Literature P. H., Moscow, 1960.

*Typhus. Infections with Natural Foci. Trans. Leningrad Pasteur Inst. of Epidemiol. and Microbiol.*, vol. XXV, 1963, 253 pp.

**Uglovoi, G. P.** Clinico-Epidemiological Characteristics of Tularemia Contracted When Threshing Various Grain Crops. *Problems of Regional., General and Exp. Parasitol. and Med. Zool.*, vol. IX, 1955.

**Vasilenko, V. S., Tinker, I. S., Shiranovich, P. I.** Control of Rat Fleas in Large Cities for Plague Prophylaxis. Comm. I. *J. Med. Parasitol. and Parasitic Diseases*, vol. XXVII, No. 4, 1958.

*Vectors of Agents of Diseases with Natural Foci.* Ed. by Prof. P. A. Petrishcheva, Moscow, Med. Literature P. H., 1962, 342 pp.

Vegetable Kingdom of the U.S.S.R. Descriptive Text for *Geobotanical Map of the U.S.S.R.*, scale 1 : 4,000,000. Ed. by E. M. Lavrenko and V. B. Sochava, vv. 1 and 2, U.S.S.R. Acad. Press, Moscow-Leningrad, 1956.

**Vereninova, N. K., Smirnova, E. I., Kalacheva, N. F., Kuznetsova, N. I., Karaseva, Z. N.** The Efficacy of Complex Vaccination Against Plague, Tularemia, Brucellosis and Anthrax. Comm. V. *J. Microbiol., Epidemiol. and Immunol.*, vol. XXIX, No. 11, 1958.

**Victor, J., Mika, L. A., Goodlow, R. J.** Studies on Mixed Infections. II. Pathological Effects of Combined *Brucella suis* and *Coxiella burneti* Infection. *Arch. Path.*, vol. LX, No. 3, 1955.

**Vlasov, Y. P.** Discovery of Sandflies in Burrows of Rodents—Large Gerbil (*Rhombomys opimus*) and Thin-Toed Suslik (*Spermophilopsis leptodactylus*).

*Coll. Articles on Parasitology, Inst. Zool., U.S.S.R. Acad. Press*, vol. III, 1932.

**Volkova, A. A., Grebenyuk, R. V., Timofeyev, A. F.** Comparative Data on Susceptibility of *Dermacentor* Ticks to Infection with Brucellae. In coll.: *Diseases with Natural Foci and Problems of Parasitology*, issue 3, Kazakh Acad. Press, Alma-Ata, 1961.

**Wegener, A.** Die Entstehung der Kontinente. *Petermanus Mitteilungen*, Bd. I, 1912.

**Wegener, A.** *Die Entstehung der Kontinente und Ozeane*, 3. Aufl., Braunschweig, 1922.

**Wisseman, Ch. L., Sweet, B. H.** *The Ecology of Dengue.* In: May J. M. *Studies in Disease Ecology.* New York, 1961.

**Yakunin, M. P.** New Natural Focus of Spirochetosis of Birds. In coll.: *Diseases with Natural Foci and Problems of Parasitology*, issue 3, Kazakh Acad. Press, Alma-Ata, 1961.

**Zabolotny, D. K.** *Pulmonary Plague in 1910-1911.* Report of the Russian Research Expedition, St. Petersburg, 1915.

**Zabolotny, D. K.** Organization and Results of Investigation of an Endemic Plague Focus. *Arch. Biol. Sci.*, vol. XXII, 1922.

**Zdrodovsky, P. F.** *Q Fever.* Med. Literature P. H., Moscow, 1955.

**Zdrodovsky, P. F., Golinevich, E. M.** *The Study of Rickettsiae and Rickettsioses.* 2nd Ed., Med. Literature P. H., Moscow, 1959.

**Zhdanov, V. M.** *Formation of Urban Foci of Infections.* Trans. Sci. Session of the U.S.S.R. Acad. Med. Sci. Held Jointly with the Ministry of Health of the Uzbek S.S.R. in Tashkent, September 20-25, 1954, Moscow, 1957.

**Zhdanov, V. M., Levi, M. I., Basova, N. N.** Etiology and Epidemiology of Acute Serous Meningitis. Comm. V. Reservoir of Choriomeningitis Virus. *Trans. Ukrainian Mechnikov Inst. of Epidemiol. and Microbiol.*, vol. XVII, 1949.

**Zhukov-Verezhnikov, N. N.** The Essence and Significance of Bacteriophagia. Comm. V. The Significance of D'Erell's Phenomenon for the Study of Bacterial Biology. *J. Microbiol., Epidemiol. and Immunol.*, vol. XVII. No. 4, 1936.

**Zhukov-Verezhnikov, N. N.** *Immunology of Plague.* Med. Literature P. H., Moscow, 1940.

**Zhukov-Verezhnikov, N. N., Khvorostukhina, M. M.** Immunology of Plague. Comm. XIV. On the Method for Production of Living Antiplague Vaccines of the Zh. V. Type. *Bull. Microbiol., Epidemiol. and Parasitol.*, vol. XIX. issue 1, 1940.

**Zilber, L. A.** *Epidemic Encephalites.* Med. Literature P. H., Moscow. 1945.

*Additional Bibliography* [1])

A Course in Epidemiology. Ed. by Prof. I.I. Elkin. Med. Literature P. H., Moscow, 1958.

*Advances in Biological Sciences*, Prague, 1962.

Agents and Vectors of Parasitic Diseases. Coll. Dedicated to the 45th Anniversary of the Scientific, Pedagogical and Public Activities of Acad. E. N.

[1]) Literature not quoted in the present book.

W 00172

Pavlovsky, Leningrad, 1954 (*Trans. Kirov Acad. of Military Med.*, vol. LVIII).

*Arch. Biol. Sci.*, vol. 56, issue 2, No. 11, 1939.

*Bratislavské lekárske listy*, r. XXXIV, Nos. 10-11, 1954 (Coll. Dedicated to Acad. E. N. Pavlovsky, Author of the Theory of Natural Nidality of Transmissible Diseases).

*Bull. Kazakh Acad. Sci.*, No. 33, Parasitol. Series, issue 4, 1946.

**Drobinsky, I. R.** Gamasid Rickettsiosis. Clinical Picture and Diagnosis. Kishinev, 1962.

**Fyodorov, V. N., Rogozin, I. I., Fenyuk, B. K.** *Plague Prevention.* 2nd Ed., Med. Literature P. H., Moscow, 1955.

Inter-Institute Scientific Conference on Problems of Regional Parasitology. Nov. 30-Dec. 4, 1962, Report Theses, Odessa, 1962.

**Korovitsky, L. K., Grigorashchenko, A. E., Stankov, G. A., Chernevskaya, L. V.** *Toxoplasmosis.* Kiev, 1962.

*Laboratory Diagnosis of Highly Virulent and Little Known Bacterial Infections.* Ed. by A. K. Shishkin and M. S. Drozhevkina. Rostov, 1959.

**Mulyarskaya, L. V.** Biocoenoses of Birds' Nests. Stalinabad., 1953 (*Trans. Inst. Zool. and Parasitol., Tadjik Acad. of Sci.*, vol. XIII).

*Natural Nidality of Diseases and Problems of Parasitology*, issue 3, Kazakh Acad. Press, Alma-Ata, 1961 (Trans. IV Conf. on Natural Foci of Diseases and Problems of Parasitol. in Kazakhstan and the Central Asian Republics, Sept. 15-20, 1959).

*Natural Foci of Infectious Diseases in Kazakhstan*, issue 2, Kazakh Academy Press, Alma-Ata, 1954 (Trans. Conf. on Natural Foci of Infectious Diseases in Man and Farm Animals in Kazakhstan. Coll. Dedicated to the 70th Birthday and 45th Anniver. of the Scientific, Pedagogical and Public Activities of Acad. E. N. Pavlovsky).

*Natural Foci of Transmissible Diseases in Kazakhstan*, issue 1, Kazakh Acad. Press, Alma-Ata, 1951.

*Neurovirus Infections.* Ed. by Corr. Member of the U.S.S.R. Acad. Med. Sci. A. A. Smorodintsev. Med. Literature P. H., Leningrad, 1954.

*Niektoré prírodno-ohniskové nákazy na Východnom Slovensku.* Sborník krajovej patológie Východného Slovenska. Prešov, 1961 (1962).

**Parnas, J.** *Antropozoonozy choroby adzwierzęce crłowieka.* Warszawa, 1960.

**Pavlovsky, E. N.** *Pappataci Fever and Its Vector.* Med. Literature P. H., Leningrad, 1947.

**Popov, V. M.** Programs and Methods of Parasitological Work at Tularemia Control Station, Tomsk, 1949.

*Problems of Epidemiology, Bacteriology, Hygiene, Parasitology, and Virology.* Theses of Reports to the Sci. Conf. of the Dushanbe Inst. Epidemiol. and Hyg. (Dec. 19-21, 1962), Dushanbe, 1962.

*Problems of Medical Parasitology.* Coll. Dedicated to the 75th Birthday and 50th Anniver. of the Scientific, Pedagogical and Public Activities of Acad. E. N. Pavlovsky, Leningrad, 1959 (Trans. Kirov Acad. of Military Med., vol. CV).

*Problems of Medical Virology*, vol. VI, Neuroinfections. Moscow, 1956.

*Problems of Regional, General and Experimental Parasitology*, vol. IV, 1949.

*Proceedings of the Plenary Scientific Conference on Diseases with Natural Foci.* Feb. 15-17, 1963, Tyumen, 1963.

*Proceedings of the Scientific Conference on Natural Foci and Prophylaxis of Plague.* February, 1963, Alma-Ata, 1963.

*Prophylaxis of Infections with Living Vaccines.* Ed. by Prof. M. I. Sokolov, Med. Literature P. H., Moscow, 1960.

*Rickettsioses. Diseases with Natural Foci.* Leningrad, 1961 (Trans. Leningrad Pasteur Inst. of Epidemiol. and Microbiol., vol. XXIII).

**Shubladze, A. K., Gaidamovich, S. Y.** Concise Course in Practical Virology. 2nd Ed., Med. Literature P. H., Moscow, 1954.

*Studies on Parasitic Vectors and Venomous Animals.* Leningrad, 1958 (Trans. Kirov Acad. of Military Med., vol. LXXXI).

Súbor prác prednesených na VIII, celoštátnom sjazde československých hygienikov, epidemiológov, mikrobiológov a infekcionistov. 25-27 septembra 1953. Bratislava, 1954.

Theses of Reports to the Scientific Conference on Natural Nidality and Prophylaxis of Plague and Tularemia. Oct. 30-Nov. 2, Rostov-on-Don, 1962.

*Transactions of the Scientific Caucasus and Trans-Caucasia Research Institute of Plague Control,* issue 1, Coll. in Memory of Prof. I. G. Ioff, Stavropol, 1956.

*Transactions of the Tomsk Institute of Vaccines and Sera,* vol. VIII. Dedicated to the 5th Anniversary of the Institute. Tomsk, 1956.

*Disease Vectors and Parasites.* Leningrad, 1951 (Trans. Kirov Acad. of Military Med., vol. XLVI).

*Zooanthroponoses.* Leningrad, 1959 (Trans. Leningrad Pasteur Inst. Epidemiol., Microbiol. and Hyg., vol. XX).

*Zoological and Parasitological Studies in 1942-1946.* Leningrad, 1948 (Trans. Kirov Acad. of Military Med., vol. XLIV).

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